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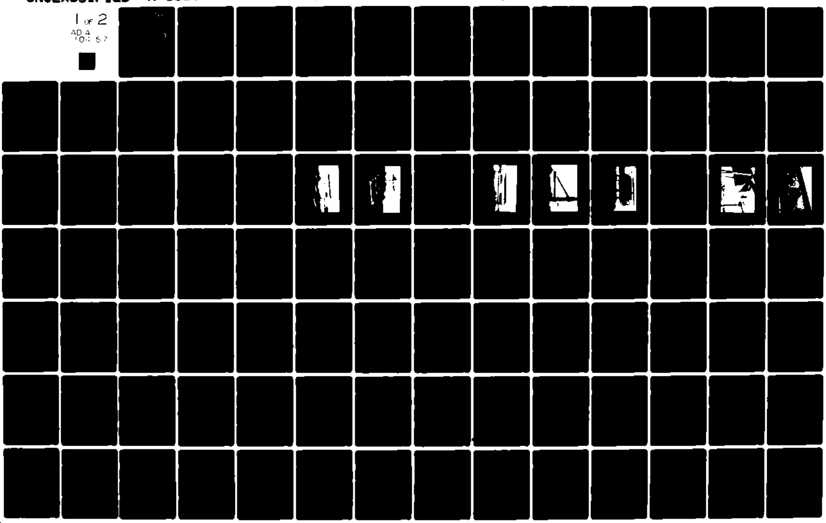

USAAVRADCOM-TR-81-D-24 LEVEL 12

AD A104157

ADVANCED TECHNOLOGY LIGHTWEIGHT GONDOLA SYSTEM EXPERIMENTAL FABRICATION PROGRAM

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July 1981

Final Report for Period August 1979 - March 1981

Approved for public release;
distribution unlimited.

Prepared for

APPLIED TECHNOLOGY LABORATORY
U. S. ARMY RESEARCH AND TECHNOLOGY LABORATORIES (AVRADCOM)
Fort Eustis, Va. 23604

APPLIED TECHNOLOGY LABORATORY POSITION STATEMENT

Previously conducted research and development effort (USAAMRDL TR 79-16, *Design Assessment of Advanced Technology Lightweight, Low Cost, Mission Configured Gondola Modules*) analyzed, assessed and selected advanced technology materials and compatible efficient design arrangements for a family of gondolas.

The program reported herein is a follow on effort to the above. This work included the design of full-scale HEGS-10 and HEGS-20 modules, the fabrication of full-scale hardware and the assembly and structural testing of the HEGS-20. This effort has provided low risk hardware to enter into engineering development, the next phase in the total development cycle.

Mr. S. G. Riggs, Jr., Aeronautical Systems Division, served as project engineer for this effort.

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The objectives of the work were to design concept verification hardware for the helicopter external gondola systems (HEGS) -10 and -20 modules, and to fabricate and test full-scale HEGS-10 and -20 assemblies. Due to funding limitations, however, the fabrication and test of verification hardware and full-scale assemblies was limited to the HEGS-20 module.

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PREFACE

This program to design, fabricate, and test a lightweight gondola system was performed under Contract DAAK51-79-C-0036 with the Applied Technology Laboratory, U. S. Army Research and Technology Laboratories (AVRADCOM), Fort Eustis, Virginia. Solomon G. Riggs, Jr., of the Applied Technology Laboratory provided technical direction for the program.

The work was performed at the Kaman Aerospace Corporation facilities in Bloomfield, Connecticut. John D. Porterfield was the principal engineer.

The author wishes to acknowledge the help of Solomon G. Riggs, Jr., whose experience and assistance was of great benefit in developing this system of gondolas. The author is also grateful to Robert Mayerjak, Joseph Rembock, and Anthony Rita of Kaman Aerospace Corporation for their aid in the development, design, analysis, and test of the gondola module system.

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INTRODUCTION

The functional and operational mission of Army cargo and utility-type helicopters emphasizes the need for the development of helicopter external gondola systems (HEGS) to provide for the effective, efficient and safe means of external transport of noncontainerized cargo. A previously conducted research and development effort (Reference 1) demonstrated the potential usefulness of a gondola system and identified essential configuration and technological improvements needed. A subsequent effort (Reference 2) assessed advanced technology materials and compatible structural design arrangements for a low-cost, lightweight, aerodynamically stable family of gondolas (HEGS-10, HEGS-20, HEGS-Palletized) functionally responsive to the operational and logistical support of Army combat and combat service support missions. The original objectives of the work to be performed under this contract were to design concept verification hardware for the HEGS-10 and HEGS-20 modules; to fabricate and test critical HEGS-10 and HEGS-20 elements/components; and to fabricate and test full-scale HEGS-10 and HEGS-20 assemblies. The work accomplished under this contract included the design of concept verification hardware and the design of full-scale HEGS-10 and HEGS-20 modules. Due to funding limitations, however, the fabrication and test of verification hardware and full-scale assemblies was limited to the HEGS-20 module.

This report presents the design of the HEGS-10 and HEGS-20 modules and the fabrication and assembly of the HEGS-20 module in the main body of the

1. GONDOLA SYSTEM FOR HELICOPTER TRANSPORT OF EXTERNAL CARGO, Brooks and Perkins, Inc., USAAMRDL-TR-77-28, Applied Technology Laboratory, U. S. Army Research and Technology Laboratories (AVRADCOM), Fort Eustis, Virginia, September 1977, AD A047560.

2. DESIGN ASSESSMENT OF ADVANCED TECHNOLOGY, LIGHTWEIGHT, LOW COST, MISSION-CONFIGURED GONDOLA MODULES, Kaman Aerospace Corporation, USARTL-TR-79-16, Applied Technology Laboratory, U. S. Army Research and Technology Laboratories (AVRADCOM), Fort Eustis, Virginia, July 1979, AD A073554.

report, the stress report for the HEGS-20 in Appendix A, and the test results for the HEGS-20 in Appendix B.

Schematics of the HEGS-10 and HEGS-30 modules are shown in Figure 1.

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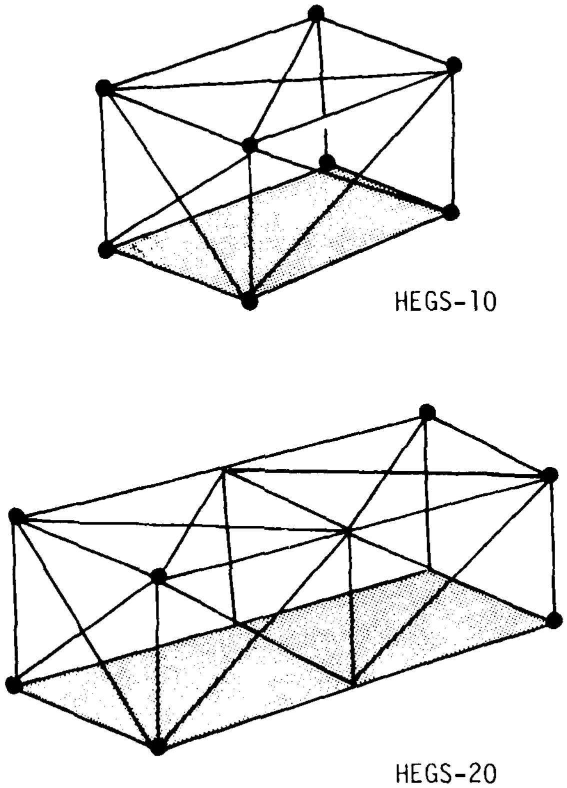
B



(Far side and far end diagonals not shown for clarity.)

Figure 1. Gondola module schematics.

DESIGN

DESIGN OBJECTIVES/PHILOSOPHY

The design criteria for the HEGS-10 and HEGS-20 modules are as follows:

1. Design empty weight shall be as light as practical. Weight goals are:

HEGS-10	600 pounds
HEGS-20	1200 pounds.

2. Payload capabilities (including weight of gondola) shall be:

HEGS-10	8000 pounds
HEGS-20	25000 pounds.

3. The modules shall be designed to provide stable aerodynamic flight characteristics in both loaded and unloaded modes.
4. The HEGS-10 and HEGS-20 shall be compatible with the CH-47D helicopter and the HEGS-10 with the BLACK HAWK using slings with sling angles not more than 30° from the vertical.
5. The modules shall be designed in accordance with AR 70-47, Engineering for Transportability, Appendix D, Criteria for Air Transport and Air Drop.
6. Effective lateral interior width for the HEGS-10 and HEGS-20 shall be the maximum attainable, consistent with design and materials, but not less than 88 in. between corner posts at the gondola ends and not less than 89-1/2 in. between the center posts of the HEGS-20.
7. The modules shall be capable of being rapidly loaded and unloaded from sides and ends, either manually or with fork-lift equipment. End and side diagonals, and end and center posts shall be capable of rapid connect and disconnect to provide accessibility and versatility.

8. The modules shall provide integral roll-on, roll-off, and drive-through capability. The floor shall be capable of sustaining loads of 300 pounds per square foot to accommodate vehicles and equipment.

9. Load asymmetry factor shall be based on a 60/40 load distribution: longitudinal and lateral.

10. The modules shall be capable of reacting impact forces associated with edge or corner strikes which may occur due to uneven terrain or uneven attitude of the gondolas during normal helicopter external cargo handling operations.

11. The modules shall be capable of being stacked two-high when loading to payload capability weight.

12. The modules shall react racking loads of 0.6 g (lateral and longitudinal).

13. The HEGS-10 shall be capable of utilization as a pallet (without upper structural truss) at payload weight of 8000 pounds.

14. The HEGS modules shall conform with dimensional specifications for 10 ft and 20 ft long containers (Figure 2). Top and bottom corner fitting openings for twist lock application (top and bottom planform) shall comply with dimensional specifications (Figures 3 and 4); however, size of side and end openings and wall thicknesses may be varied.

15. To achieve commonality of components, the same vertical corner columns, upper and lower corner fittings, diagonal assemblies, and attaching hardware may be used for both HEGS-20 and HEGS-10 modules.

The initial design task performed during this program was to verify the technical data pertaining to the HEGS-10 and HEGS-20 modules developed under Contract DAAK51-78-C-0012 for compliance with the foregoing design criteria

S = Length between centers of apertures in corner fittings

P = Width between centers of apertures in corner fittings

C_1 = Corner fitting measurement: 4 +0-0.06 inches (101.5 +0-1.5 mm)

C_2 = Corner fitting measurement: 3.5 +0-0.06 inches (89 +0-1.5 mm)

L = External length of container

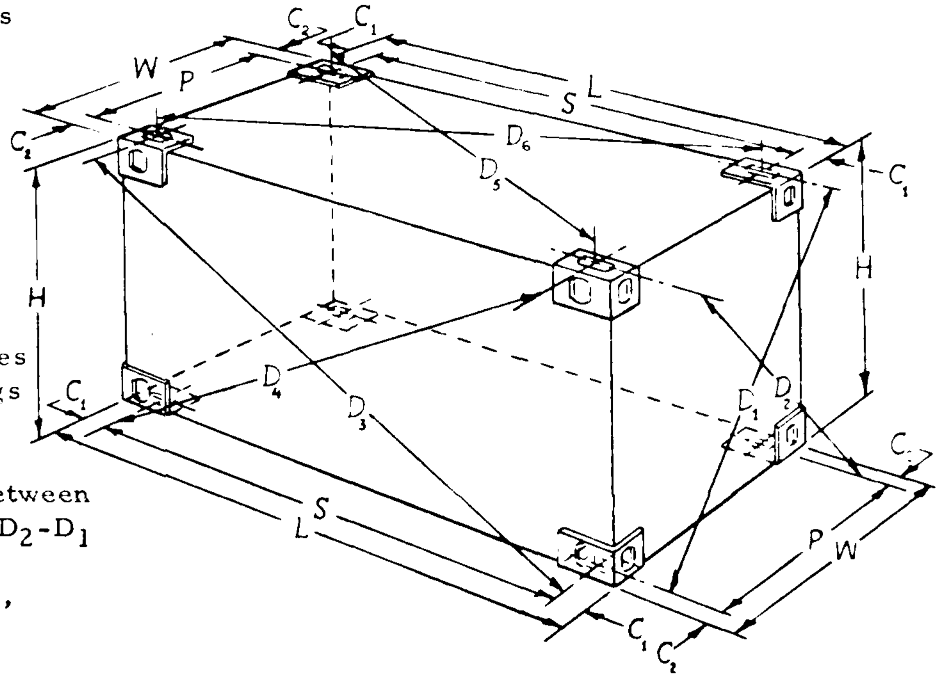
W = External width of container

D = Distance between center of apertures of diagonally opposite corner fittings resulting in six measurements: D_1, D_2, D_3, D_4, D_5 and D_6

K_1 = Difference between D_1 and D_2 or between D_3 and D_4; i.e., $K_1=D_1-D_2$ or $K_1=D_2-D_1$ or $K_1=D_3-D_4$ or $K_1=D_4-D_3$

K_2 = Difference between D_5 and D_6; i.e., $K_2=D_5-D_6$ or $K_2=D_6-D_5$

H = Overall height



Nominal Length Feet	Length Overall (L)		S			P			K_1 Max.		K_2 Max.	
	mm	Ft In.	mm	Ft	In.	mm	Ft	In.	mm	In.	mm	In.
20	6055 + 3-3	19 10.50 +0-0.25	5853	19	2.44	2259	7	4.97	13	0.50	10	0.38
10	2990 + 1-4	9 9.75 +0-0.18	2787	9	1.72	2259	7	4.97	10	0.38	10	0.38

Width Overall (W): 8 ft 0 in. + 0-0.18 in. (2435 + 3-2mm)
Height Overall (H): 8 ft 6.5 in. + 0-0.75 in. (2600 + 3-16 mm)

NOTE: Dimensions S and P are reference dimensions only. The tolerances to be applied to S and P are governed by the tolerances shown for the overall length (L) and overall width (W).

Figure 2. Gondola dimensions.

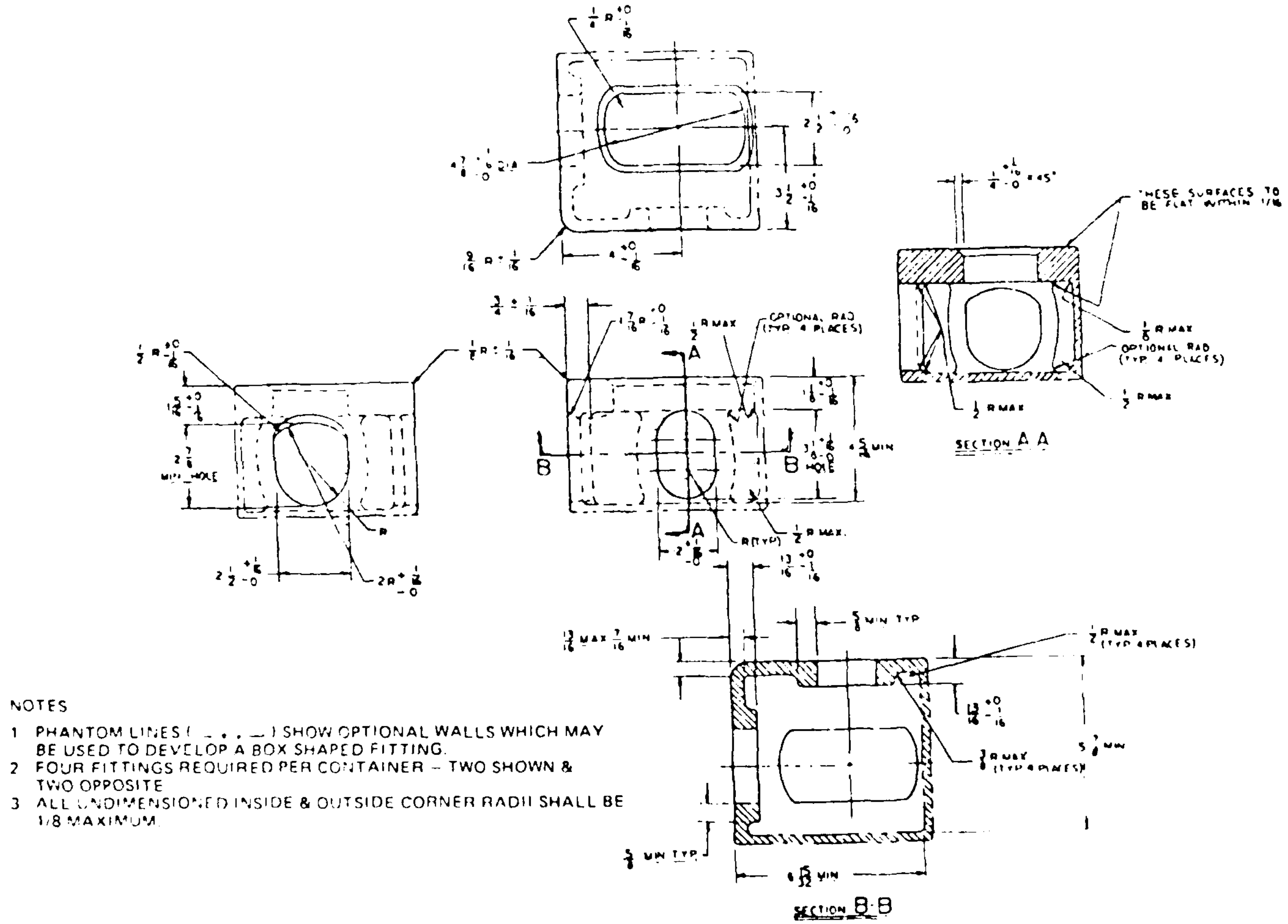
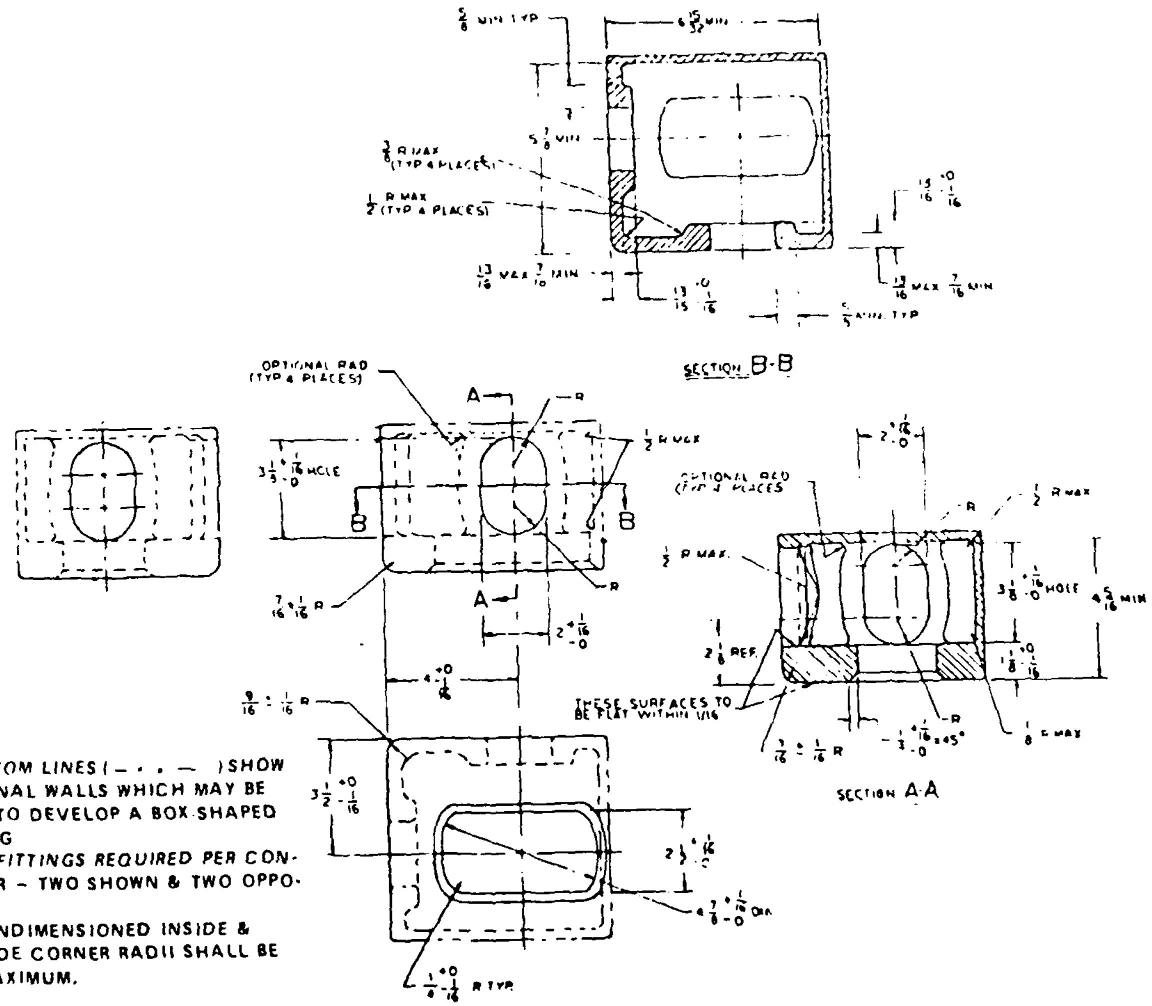


Figure 3. Top fitting (dimensions in inches).



NOTES:

1. PHANTOM LINES (— · · —) SHOW OPTIONAL WALLS WHICH MAY BE USED TO DEVELOP A BOX-SHAPED FITTING
2. FOUR FITTINGS REQUIRED PER CONTAINER – TWO SHOWN & TWO OPPOSITE
3. ALL UNDIMENSIONED INSIDE & OUTSIDE CORNER RADII SHALL BE 1/8 MAXIMUM.

Figure 4. Bottom corner fitting (dimensions in inches).

(see Reference 2). This task was accomplished by:

1. Establishing NASTRAN finite element models for the HEGS-10 and HEGS-20 to be used in determing the loads/stresses for the critical suspension condition (single-point or two-point suspension).

2. Using the member sizes and material properties presented in Reference 2, determining the loads/stresses acting on the individual structural members of the HEGS-10 and HEGS-20 modules for the critical suspension condition by means of a finite element computer program

3. Calculating the loads and reactions acting on the HEGS-10 and HEGS-20 module members for the longitudinal and lateral racking condition, as well as for the two-high stacking condition by using force equilibrium methods.

4. Determining the maximum loads/stresses acting on the members of the HEGS-10 and HEGS-20 modules for the above conditions investigated.

5. Determining the adequacy of each member for supporting the loads acting on it.

Results of the NASTRAN performed for the HEGS-10 and HEGS-20 modules were in good agreement with the loads, stresses, and margins of safety presented in Reference 2. It was therefore concluded that the data presented in Reference 2 was valid and consistent with the requirements of this program.

HEGS-20 MODULE

The basic configuration of the HEGS-20 module is shown in Figures 5 and 6.

HEGS-20 Floor Structure

The floor structure of the HEGS-20 module is essentially the same as described in Reference 2, with the major modifications being the size and

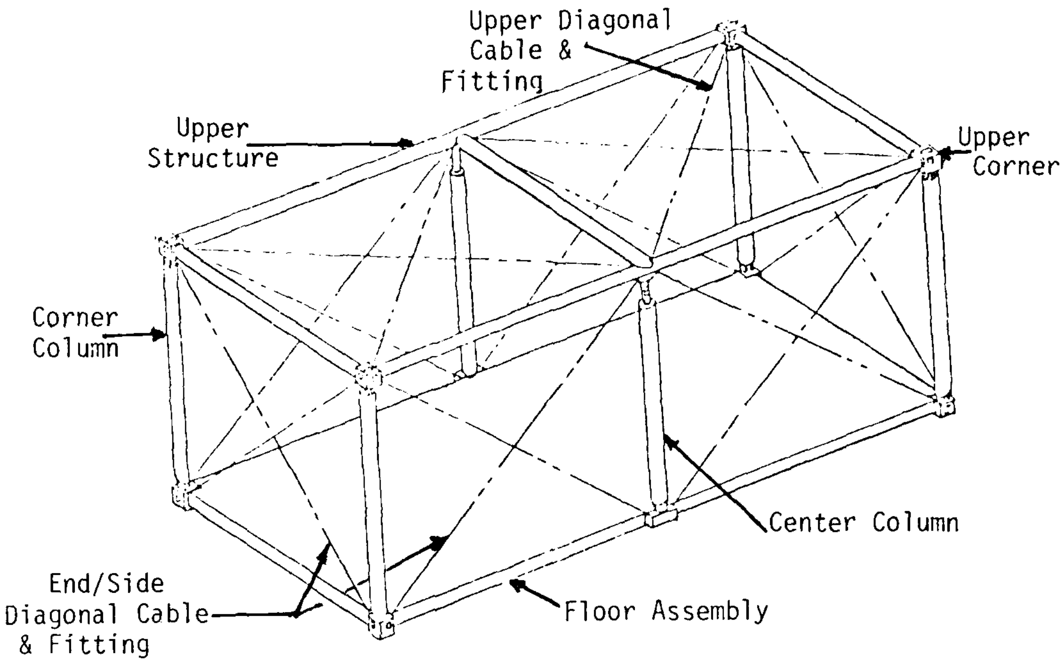


Figure 5. Superstructure - HEGS-20.

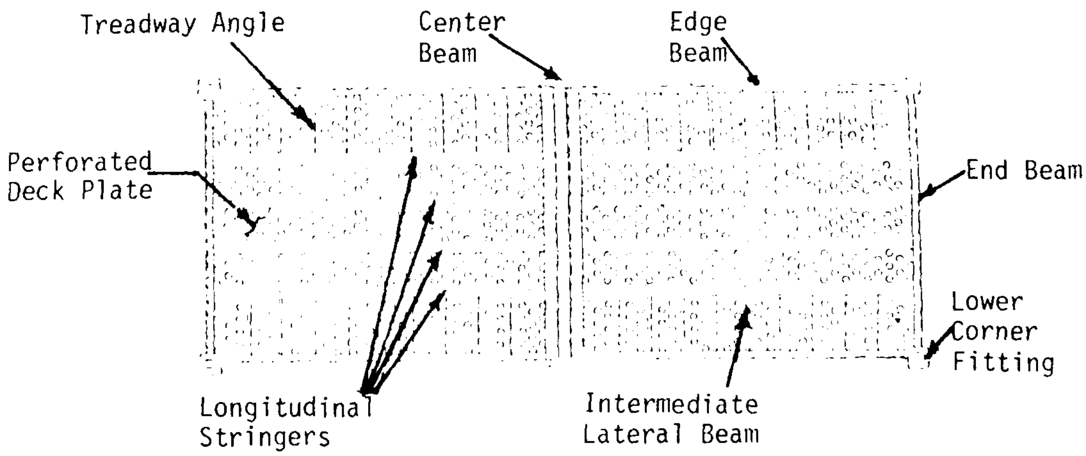


Figure 6. Floor assembly - HEGS-20.

location of the deck perforations, and the strengthening of the HEGS-20 edge members. The pattern for the 2-1/4-inch-diameter holes in the deck plate is based on a staggered 3-15/16-inch-square grid which would permit the use of both longitudinally and laterally oriented roller systems interchangeable on the HEGS-10 and HEGS-20 modules. The edge beams are strengthened to increase the ability of the floor structure to support the required loading while resting on uneven ground with the side diagonals and the center columns removed.

The torsionally flexible HEGS-20 floor assembly consists of the following members fabricated from 5456 aluminum alloy plate and extrusions:

1. Channel end beams
2. Modified H-beam edge beams
3. T-shaped stiffeners and cross beams
4. Treadway angles
5. Built-up plate center beams
6. Center column and diagonal plate support structure
7. Perforated deck plate
8. Lower corner fitting assemblies.

The floor system design is capable of resisting large overloads by structurally efficient membrane action of the perforated deck plate wherein the membrane action allows the loads to be supported primarily by axial tension rather than bending.

Fifty standard flush-mounted tie-down rings are systematically located on the perforated deck plate to facilitate cargo restraint. These rings are attached to the undersurface of the perforated deck plate by stainless steel blind rivets.

HEGS-20 Upper Frame Assembly

The upper frame assembly for the HEGS-20 module consists of four upper corner fittings, two upper frame center fittings, and 5-inch schedule 5 6061-T6 aluminum pipe used for the upper ends, center, and side members. The upper center fittings provide a means of attaching the upper diagonal fitting assembly or the upper diagonal cables, the side diagonal cable assembly, the upper end of the vertical center columns, and the side and center sections of 5-inch schedule 5 pipe. Tooling fixtures are used prior to and during final weld to insure the proper location of the upper surface apertures of the upper corner fittings. Rub strips consisting of 2 x 2 x 3/16-inch 6061-T6 aluminum angles are welded to the end and side members to aid in the positioning of the container lift adapter during hook-up operations.

Upper Corner Fitting

Design features and considerations affecting the design of the upper corner fitting assembly consisting of the basic box structure, diagonal clevises, vertical column lug, and upper structure welding stubs are:

1. The basic box structure is fabricated by welding sections of 5456-H116 aluminum plate together.
2. The thickness of the upper plate (1-1/8 inches) and the size and center location of the twist lock aperture are in accordance with the requirements of this program.
3. Lugs used for attaching the vertical corner columns and clevises used for attaching the upper end and side diagonals are machined from 5456-H116 aluminum plate and are then welded to the basic box structure.
4. The upper structure is attached to the basic box structure by welding thick wall 6061-T6 aluminum pipe stubs to the two interior sides of the box structure. The outer

diameter of these stubs is premachined to form a slip-fit with the inside diameter of the upper structure pipe. This slip-fit permits the centers of the twist lock apertures of the four corner fittings to be closely positioned during the final welding of the upper structure pipe to the pipe stubs.

5. The basic box structure, vertical column lugs, and diagonal clevises of the upper corner fitting are common to both the HEGS-10 and HEGS-20 modules. The weld stubs for the upper structure, however, are smaller in diameter for the HEGS-10 module to reflect the lower loads acting on the HEGS-10 structure.

6. Holes are provided on the two exterior sides of the box structure of the upper corner fitting to permit the use of chain lifting slings. The locations of the chain holes were selected to minimize eccentricities between the applied loads and their reactions, to minimize the bending moments applied to the structure, and to insure that the major portions of the lifting loads will be reacted directly by the 1-1/8-inch-thick upper plate to minimize wear on the thinner side plates.

7. Monoball bearings are installed in the column lugs to permit rotation at the end of the columns during hard landings and thus avoid potential damage.

8. The feasibility of permanently attaching lifting eyes to the upper corner fitting as a substitute for the chain holes in the upper corner fitting was investigated. Factors considered in this study were:

    a. The space envelope available for attaching lifting eyes without interfering with the operation of the container lift adapter.

b. The eccentricity of the lifting eye to the gondola's structure and the resultant increase in the twisting and bending moments that would be applied to the upper corner fitting and the upper structure.
c. The alteration to the upper corner fitting to provide a mounting surface for the lifting eye.
d. The increase in size and weight of both the upper corner fitting and upper structure required to accommodate the increase in twisting and bending moments due to the eccentric lifting eye.

It was concluded that the addition of lifting eyes to the upper corner fittings would greatly increase the size, weight, and complexity of the upper corner fitting and the upper structure of both the HEGS-10 and HEGS-20 modules. The preferred design shown herein allows the bottom edge of the 1-1/8-inch-thick plate to sustain the potential wear of the lifting chain without reducing the structural or functional capacity of the upper corner fitting.

Lower Corner Fitting (HEGS-10 and HEGS-20)

Design features and considerations affecting the design of the lower corner fitting assembly consisting of the basic box structure and vertical column lug are:

1. The box structure and the vertical column lug weldment are fabricated from 5456-H116 aluminum plate.
2. The thickness of the lower plate (1-1/8 inches) and the size and center location of the twist lock aperture are in accordance with Figures 2 and 3.

3. Slots are provided to accommodate the T-bar fitting of the end and side diagonals.
4. The end beam, edge beam and deck plate of the floor structure are welded to the lower corner fitting.
5. Holes are provided through the exterior sides of the lower corner fitting for debris clean-out and, in the case of the HEGS-10 floor when used as a pallet, for attaching chain lifting slings. The location of these holes was chosen to minimize eccentricities between the applied loads and their reactions and to insure that the chain lifting sling will bear on the thick upper plate of the fitting instead of on the thinner sidewalls.
6. Monoball bearings are installed in the column lugs to permit rotation at the ends of the columns during hard landings and thus avoid potential damage.
7. A gusset welded to the upper surface of the corner fitting and the vertical column lugs is used to protect the lug from damage during loading and unloading operations.

Corner Vertical Column (HEGS-10 and HEGS-20)

The corner vertical column shown on Figure 6 consists of thin-wall 6061-T6 aluminum tube to which 6061-T6 aluminum clevis-type fittings are welded at each end. The configuration shown meets the following conditions and criteria:

1. The 3-3/4-inch-diameter tube, and its location, is compatible with the 96-inch maximum gondola width and the minimum 88-inch clear-distance-between-corner column requirements.
2. The cross-sectional dimensions, 3-3/4 inch O.D., .125 inch wall thickness, and the physical properties of the 6061-T6

aluminum alloy are compatible with the applied loads and impact considerations.

3. The column assembly is readily repairable by welding.

4. The physical size of the clevis end fittings is proportioned to sustain the rough handling associated with the Army environment.

5. The length of the corner column and the dimensions of the upper and lower corner fittings are compatible with the 8-foot, 6.5 $\pm$ .75-inch overall height requirement.

6. The columns are attached to the upper and lower corner fitting lugs by means of pins, which is compatible with the desire for rapid assembly or disassembly, high strength, low weight, and low cost. The only tool required for assembly or disassembly is a pair of pliers.

Center Vertical Column Assembly

The center vertical column assembly of the HEGS-20 module (Figure 6) consists of a 3.75-inch-diameter x .125-inch-thick wall 6061-T6 aluminum tube to which a square-ended 6061-T6 aluminum fitting is welded to the lower end and a 17-4 PH stainless steel screw jack having a round end is riveted to the upper end. The center vertical column design is compatible with the following conditions and criteria:

1. The center column and its installation of HEGS-20 module is compatible with the minimum 89-1/2-inch clear-distance-between-center-columns requirement at its lower end to permit the loading of 463L pallets.

2. The upper screw jack fitting is constructed of corrosion resistant stainless steel to insure its proper operation when subjected to the Army's hostile environment.

3. A permanently installed handle is provided for rotating the upper portion of the screw jack during assembly and disassembly operations.

4. The upper end of the screw jack is machined round to permit rotation of the jack while it is engaged in the round hole provided in the upper structure.

5. The lower end fitting of the center column is machined as a square to prevent the rotation of the column while the screw jack is being operated and while the column is engaged with the square hole provided in the floor structure.

6. The center column is designed to withstand compression loads that are primarily associated with the racking condition. Any tendency for the upper structure to lift off the center column will be resisted by tension in the side diagonals attached to the upper structure near the upper end of the center column.

Side and End Diagonal Fittings and Diagonal Cable - HEGS-10 and HEGS-20

The side and end diagonals to be used on both the HEGS-10 and HEGS-20 modules consist of Kevlar cable assemblies attached to adjustable stainless steel end fitting assemblies. The upper ends of the cables are attached semipermanently to the clevises of the upper corner fittings and, in the case of the side diagonals for the HEGS-20 module, also to clevises mounted near the center of the upper structure. Conventional pins are used to effect this attachment. The lower ends of the cable assembly are also pinned to the diagonal fitting assembly consisting of a threaded clevis, a turnbuckle barrel, and a threaded T-bar end fitting. The T-bar end fittings are inserted into the slots provided in the lower corner fittings and, in the case of the side diagonals for the HEGS-20, into slots provided in the floor structure at the center beam. Once the T-bar fittings are inserted into the slots, they are twisted 90 degrees to effect the lower end

connection. The turnbuckle is then rotated to obtain the desired tension in the diagonal assembly. Thus, assembly and disassembly can be rapidly and easily accomplished.

Kevlar cable assemblies were chosen because of their high strength-to-weight ratio and their flexibility. The same diameter Kevlar cables are used for both side and end diagonals for the HEGS-10 and HEGS-20 modules.

Handles semipermanently attached to the turnbuckle barrel and clevis are provided for applying torque to the turnbuckle barrel for tensioning the diagonal assembly and to prevent twisting of the Kevlar cable during this operation.

The clevis, turnbuckle barrel, and T-bar fitting of the diagonal fitting assembly are machined from 17-4 PH stainless steel and heat-treated to Condition 1025 to insure their trouble-free operation in the Army's environment.

During unloading operations, with the floor of either the HEGS-10 or HEGS-20 module resting on uneven ground, some of the diagonals may be loaded well above their preload value due to floor racking. The diagonal assemblies will not store very much energy when subjected to normal loads due to the high stiffness of the Kevlar cables and the 17-4 PH stainless steel end fittings. In extreme cases, however, there may be sufficient energy stored in the floor or superstructure to cause the diagonal assembly to whip if suddenly released. A rivet is installed near the threaded ends of the T-bar and clevis fittings after assembly with the turnbuckle barrel as a safety precaution to prevent them from becoming accidentally disengaged during removal operations.

Upper Diagonal Fitting Assembly and Upper Diagonal Cable - HEGS-10/HEGS-20

The upper diagonal assembly consists of the upper diagonal fitting assembly and the upper diagonal cable. During normal operations, the upper

diagonal assemblies will be lightly loaded and will only come into play when the rigid upper frame distorts under severe racking loads. The upper fitting assembly consists of a threaded rod end fitting for attachment to the upper corner clevis, a turnbuckle barrel, and a threaded clevis for attaching the upper cable assembly. Check nuts are used to prevent the loss of preload due to turnbuckle barrel rotation during operation.

The 20,000-pound-capacity diagonal cable assembly is fabricated from Kevlar and the end grommets are 6061-T6 aluminum alloy. One end of the cable is attached to the clevis end of the diagonal fitting assembly and the other end is attached to the upper corner fitting clevis. Flanged 5/8-inch-diameter steel pins are used for attaching the upper diagonal fitting assembly and the upper cable assembly to each other and to upper structure clevises.

Step Assemblies - HEGS-10 and HEGS-20

Steps attached to the two corner columns on one side of the HEGS-10 module and to two corner columns and a center column on one side of the HEGS-20 module are provided to aid personnel in attaching lifting slings to a helicopter's cargo hooks. These steps are capable of being indexed every 30 degrees around the 360-degree azimuth and may be lifted vertically for stowage against the upper structure.

The steps consist of a weldment of a 3- x 1.5-inch 6061-T6 aluminum tread, a 1-1/2-inch-diameter x .058-inch-thick 6061-T6 aluminum tube diagonal strut, and a section of 4-inch schedule 80 6061-T6 aluminum pipe vertical sleeve that slides over the corner and/or center columns. The lower portion of the vertical sleeve has lugs spaced every 30 degrees in azimuth for locking it to the support segments that are riveted to the columns.

The location and dimensions of the support segments are such that the inner and outer dimensional envelopes are not exceeded.

HEGS-10 MODULE

Much of the foregoing design description for the HEGS-20 is also applicable to the HEGS-10 module due to the duplicity of many of the components making up the assemblies for each module. Components such as the upper and lower corner fittings, corner columns, side and end diagonal fittings and cables, as well as the upper diagonal fittings and cables, are common to both the HEGS-10 and HEGS-20 modules. Figures 7 and 8 present the basic components for the HEGS-10 module. The HEGS-10 components not previously discussed are described in the following paragraphs.

HEGS-10 Floor Assembly

The details of the HEGS-10 floor structure are similar to those previously described for the HEGS-20 floor assembly; major differences are the size of the edge members and the elimination of the heavy buildup center beam. The edge beams used for both the HEGS-10 and HEGS-20 modules are fabricated from 5456-H111 aluminum 5 x 5 x .313 inch H-beams. In the case of the HEGS-10 module, the two exterior flanges of the H-beam are completely removed to form a modified channel section, whereas in the more highly loaded HEGS-20 module, only the upper external flange is completely removed. Due to the smaller length of the HEGS-10 floor structure (10 feet as opposed to 20 feet), no intermediate reaction point is required to support the floor, thus permitting the elimination of the center beam as used for the HEGS-20 floor structure. The main structural members making up the HEGS-10 floor assembly are:

1. Channel end beams fabricated from 5456-H111 aluminum 5 x 5 x .313 inch H-beams
2. Channel edge beams fabricated from 5456-H111 aluminum 5 x 5 x .313 inch H-beams
3. Longitudinal stiffeners and traverse center beams fabricated from 5456-H111 aluminum S5 x 2.5T tee extrusions

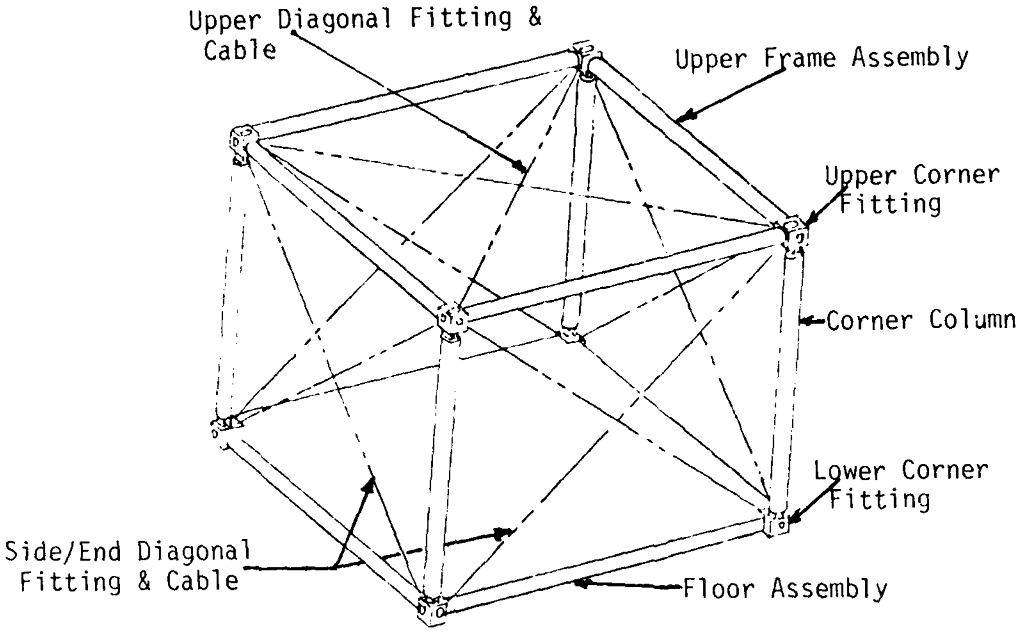


Figure 7. Superstructure - HEGS-10.

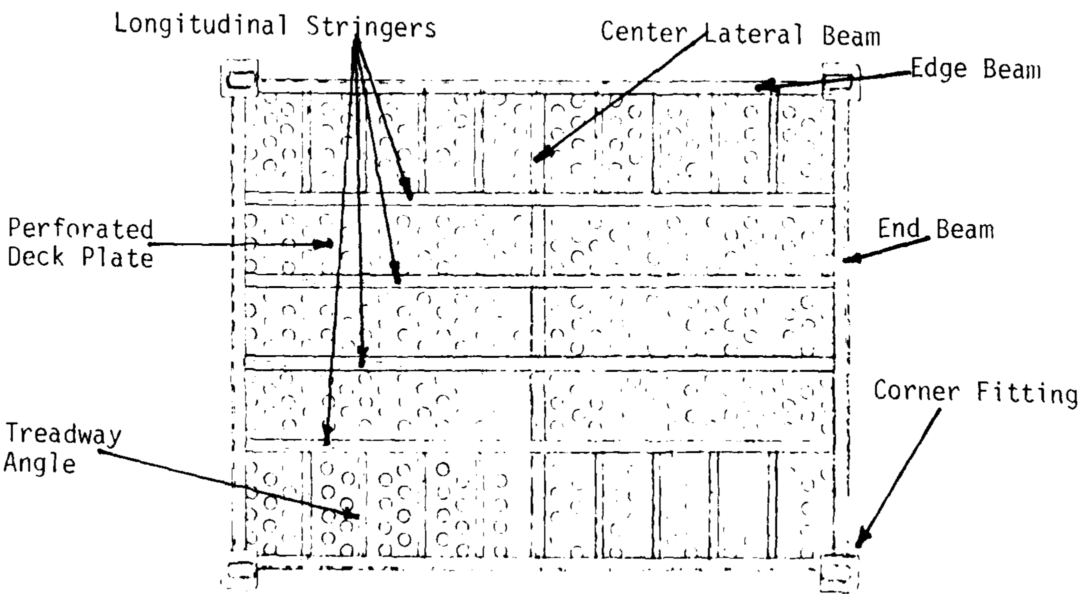


Figure 8. Floor Assembly - HEGS-10.

4. Treadway stiffeners made from 5456-H111 aluminum 3 x 2 x 3/16 inch angles

5. Perforated deck plate made from 3/16-inch-thick 5456-H321 aluminum plate

6. Lower corner fitting assemblies.

Twenty-five flush mounted tie-down rings are riveted to the underside of the perforated deck plate for cargo restraint.

HEGS-10 Upper Frame Assembly

The upper frame assembly consists of four upper corner fittings connected by 4-1/2-inch-diameter x .049-inch-thick 6061-T6 aluminum tubing. Apertures in the upper surface of the upper corner fittings are located by suitable tooling prior to/and during final welding of the 4-1/2-inch-diameter tubing to the 4-inch schedule 40 pipe stubs of the upper corner fittings to insure their proper positioning.

Estimated Weight Summary

ITEM	HEGS-10	HEGS-20
Top Frame	89.5 Lbs.	230.0 Lbs.
Vertical Tubes	58.4	99.3
Diagonals	35.2	59.4
Diagonal Hardware	55.7	86.7
Floor	456.5	954.9
Miscellaneous Hardware	16.7	28.9
TOTAL	712.0 Lbs.	1459.2 Lbs.

FABRICATION AND ASSEMBLY OF THE HEGS-20 MODULE

FABRICATION

Figures 9 and 10 show the assembled HEGS-20 module. Standard manufacturing processes and techniques such as machining, welding, and riveting were used to fabricate the floor assembly, upper structure, corner and center column assemblies, and diagonal end fittings. The diagonal cables, made from Kevlar, were certified as to strength and commercial quality welding techniques were used for all weldments.

A special tooling fixture was used to locate the centers of twist lock apertures in the lower corner fitting of the floor assembly and in the upper corner fittings of the upper structure. These aperture locations must be controlled to insure compatibility with automated lifting devices and with ground handling equipment. As the locations of the upper apertures are identical to the location of the lower apertures, the same tool was used to fabricate the floor assembly and the upper structure.

Some difficulties were experienced in controlling distortions caused by weld shrinkage during the fabrication of the first HEGS-20 floor assembly. These distortions were primarily encountered while welding the perforated deck plate to the floor grid members. Tack welds, used to temporarily position the deck plates, restricted the thermal growth and contraction of these plates when the plate-to-floor grid welds were being made. This resulted in the deck plates deforming out-of-plane between the floor grid members, particularly at each end of the floor structure.

Deck plate deformations were reduced by adding intercostals between the floor grid members at locations of maximum plate deformation, pulling the plate down to the desired vertical position, and welding the plate to the intercostals. Experience gained during the fabrication of floor assembly was utilized to revise the welding procedures and sequences for use during

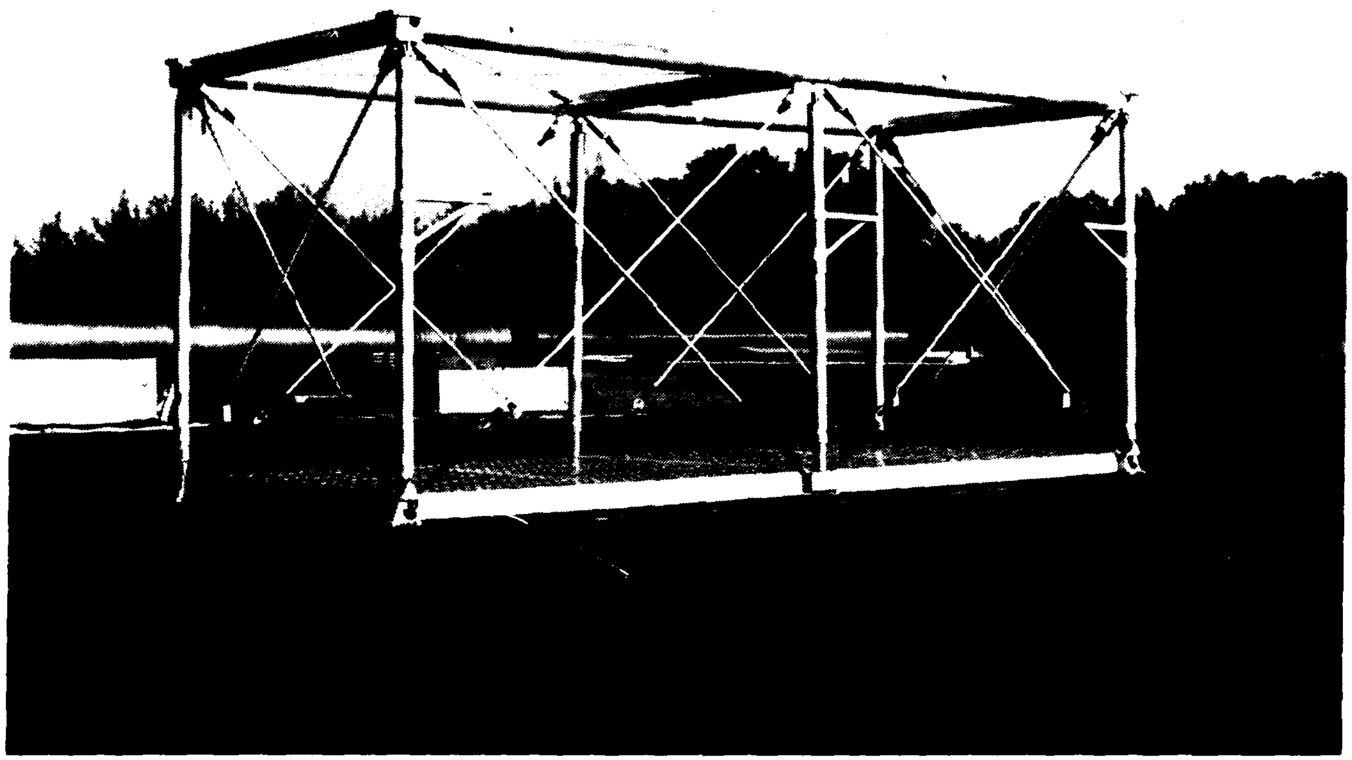
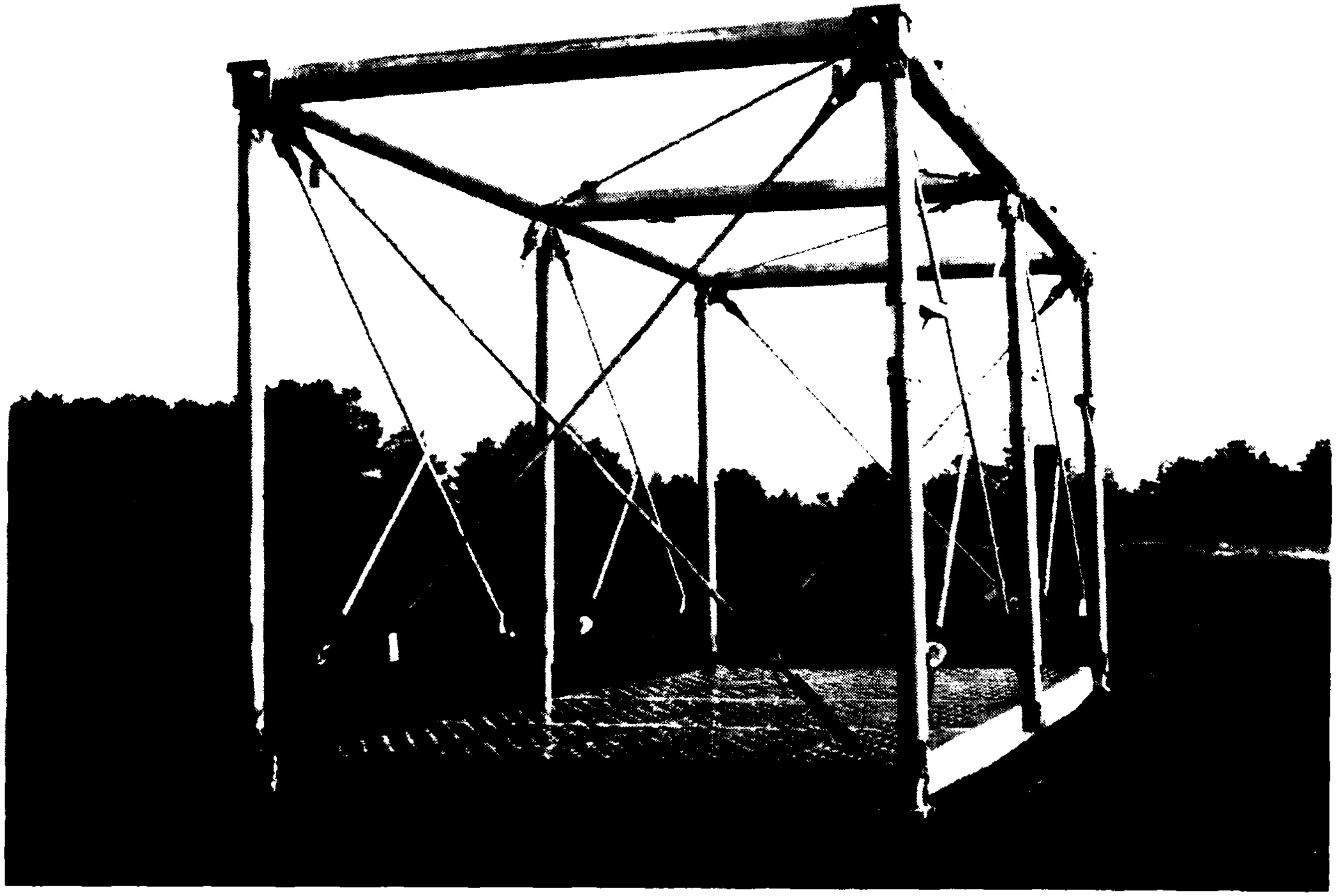


Figure 9. HEGS-20 module assembly - side view.



[illegible] - end view.

the fabrication of the second floor assembly. Consequently, the fabrication of the second floor assembly proceeded without encountering the deck plate deformation difficulties.

ASSEMBLY

The HEGS-20 module is assembled in the following manner:

1. Corner columns are first pinned to the lugs of the lower corner fittings of the floor assembly as shown in Figure 11. A washer and cotter pin are used to retain each of the attachment pins.
2. Steps shown in Figure 12 are installed on two corner columns located on one side of the module by slipping them over the upper free end of the columns.
3. The upper diagonal assemblies are installed in the upper structure by means of attachment pins, washers, and cotter pins. The upper diagonal assemblies are tightened by rotating the turnbuckle using two suitable wrenches--one to rotate the turnbuckle and the other to prevent windup of the Kevlar cable. Locknuts are then tightened against both ends of the turnbuckle to prevent loosening of the diagonal assembly during operation.
4. The upper structure is lifted into position by means of a hoist, forklift, or crane. Attachment pins are used to connect the lugs of the upper corner fittings to the upper clevises of the corner columns. Washers and cotter pins are used to retain the attachment pins.
5. Side and end diagonal assemblies are attached to the upper structure clevis mounted on the upper corner fittings by means of pins, washers, and cotter pins. Figure 13 shows the HEGS-20 module after the upper structure has been

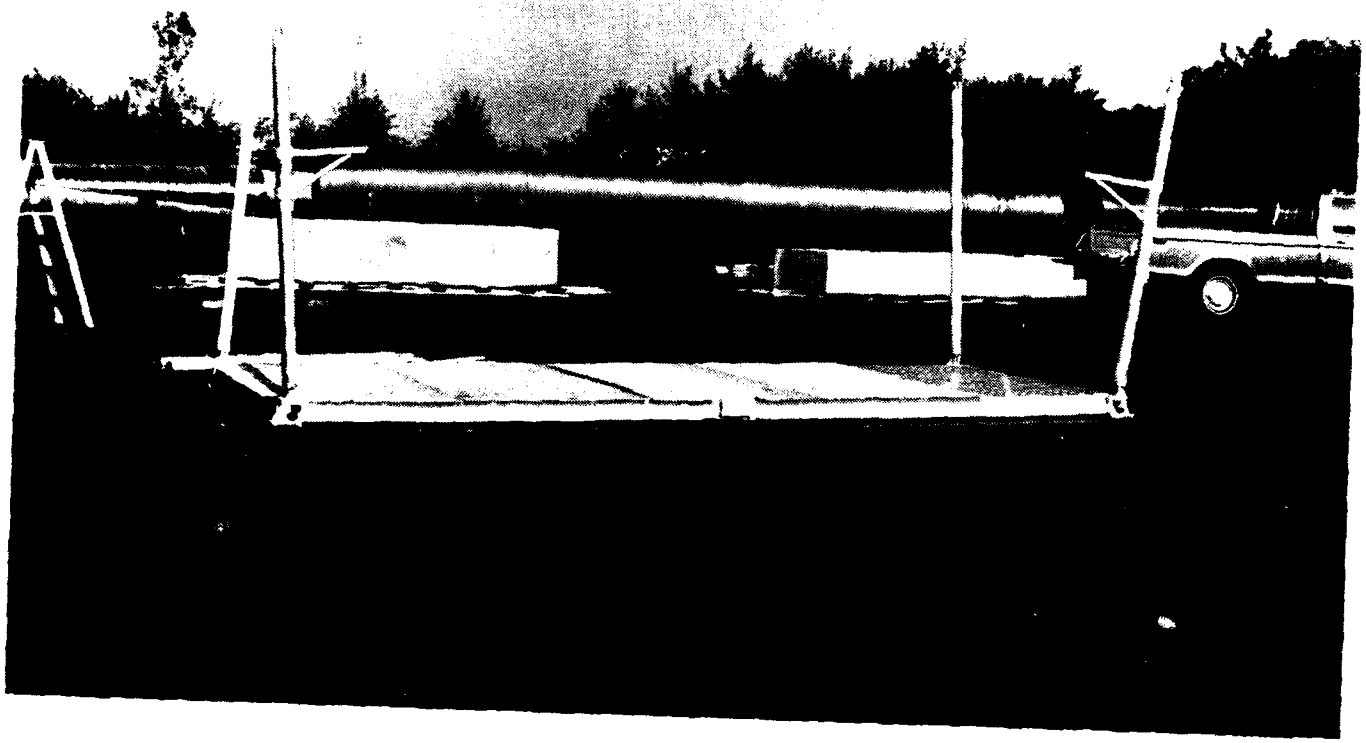


Figure 11. Corner columns attached to floor.

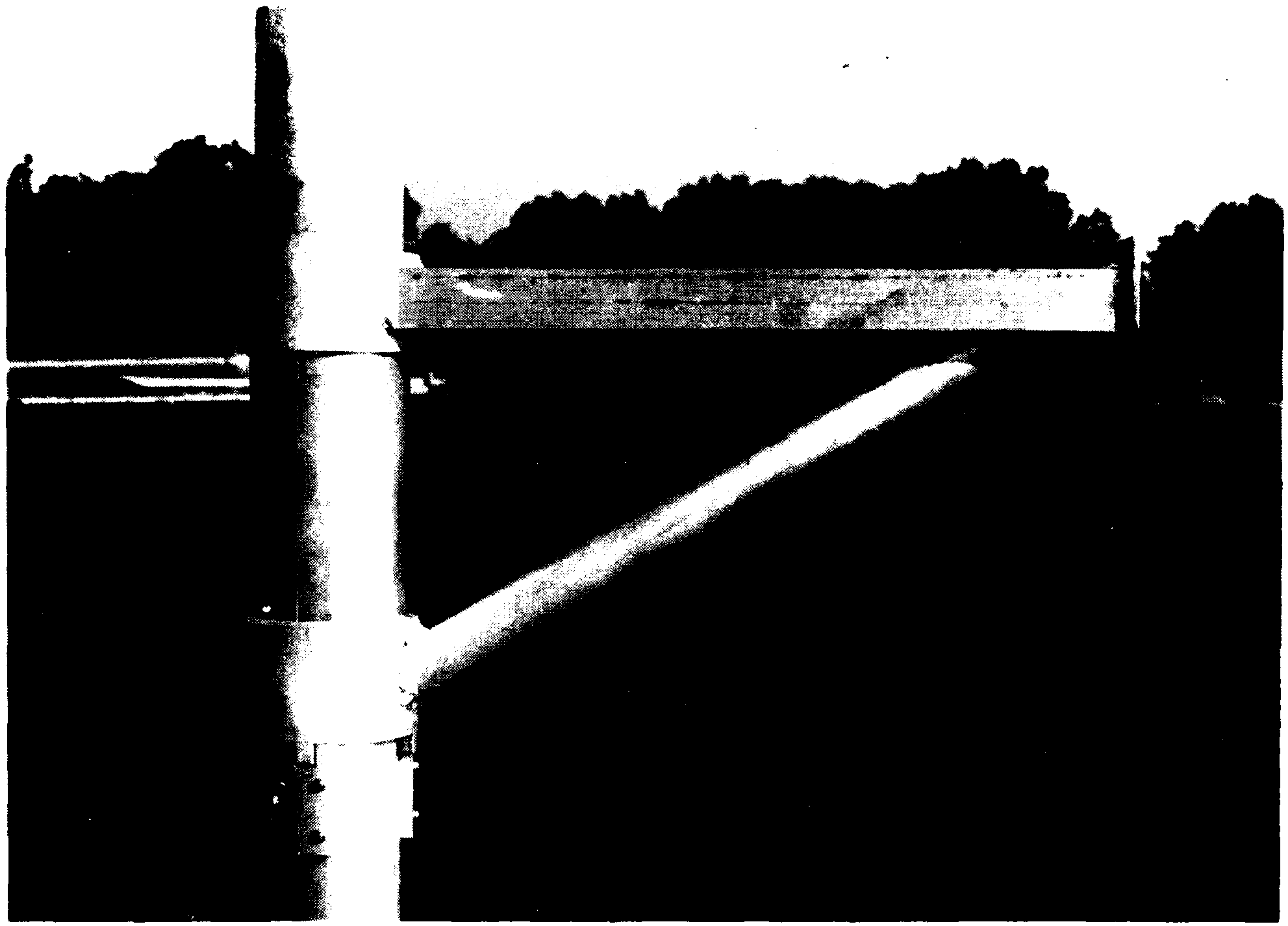


Figure 17. Stem assembly.

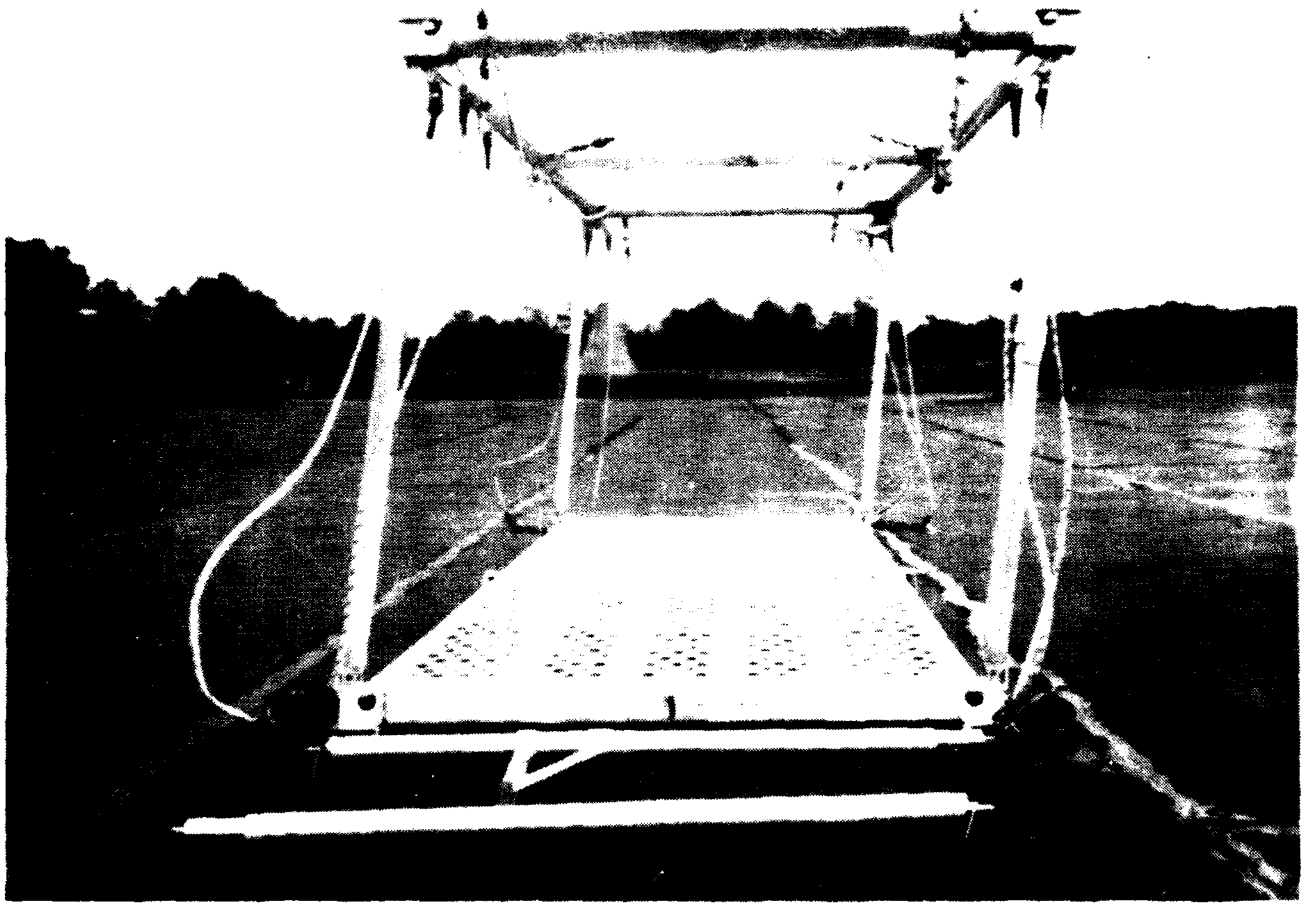


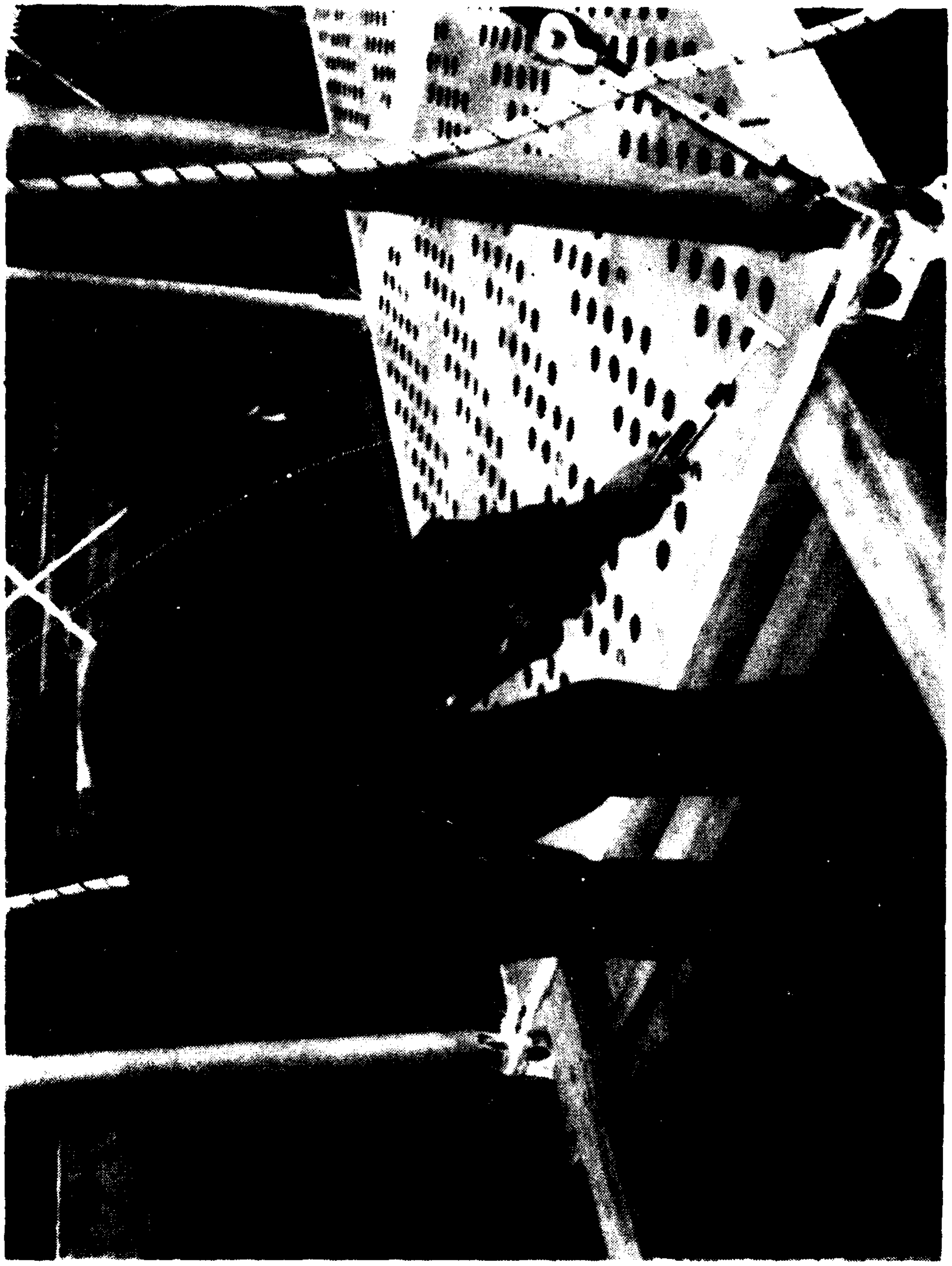
Figure 1[illegible]. WCS-20 motor structure attachment.

attached to the upper ends of the four corner columns and after the side and end diagonal assemblies have been attached to the upper structure.

6. Center columns are installed by inserting the lower square end fitting of the center column into the square hole of the center column diagonal support structure located on the sides of the floor assembly. The round stub portion of the upper end of the center column's jack screw is aligned with the round hole provided in the lower center surface of the upper structure. The jack screw is rotated until the round stub is fully inserted into the upper structure with the horizontal axes of the floor assembly and the upper structure being approximately parallel. In the interest of consistency, the center column having the step attached to it should be installed on the same side of the module as the corner column steps.

7. The T-bar ends of the side and end diagonals are inserted in the slots provided in the lower corner fittings and in the center column, diagonal support structure located on each side of the floor structure as shown in Figures 14 and 15. Once inserted, the T-bar fittings are rotated 90 degrees and the diagonal fittings are tightened by rotating the turnbuckles.

8. When properly rigged, the side and end diagonals should be tight and the difference in length between any set of diagonals should be 1/2 inch or less.



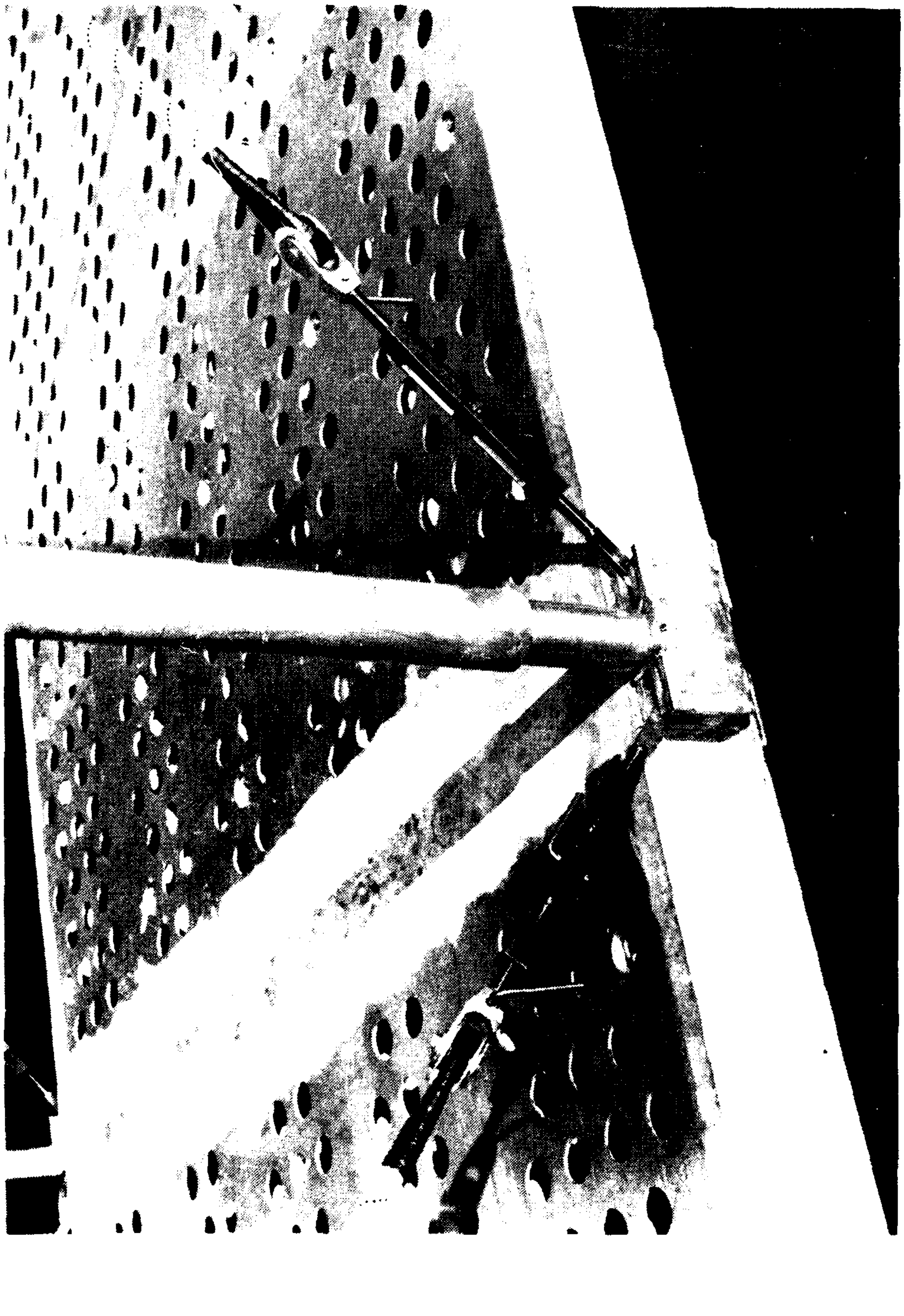


Figure 15. HEGS-20 lower center T-bar installation.

CONCLUSIONS

1. The objectives of this program, i.e., to design concept verification hardware for the HEGS-10 and HEGS-20 modules and to fabricate and test critical elements/components and full-scale HEGS-20 gondola assemblies, have been successfully accomplished.

2. The following HEGS-20 module characteristics were demonstrated during the design, fabrication, and testing phases of this program:

   a. High structural efficiency of approximately 40 to 1 through the use of new structural concepts and materials.

   b. High impact resistance potential through the use of flexible structural elements/components.

   c. Ready producibility by standard commercial machining and welding procedures.

   d. Easy repairability by commercial welding standards and techniques without the requirement for post heat treatment.

   e. Easy maintenance due to the high corrosion resistance of 5456 and 6061 aluminum alloys used in the fabrication.

   f. Functional/structural capabilities not impaired by the occurrence of small amounts of plastic deformations.

   g. Rapid load-unload capabilities through the use of adjustable T-bar diagonal end fittings, flexible high-strength Kevlar diagonal cables, and easily installed/removed center jack-post columns.

   h. Versatile cargo tie-down capability through the use of 50 flush-mounted tie-down rings systematically located.

   i. Compatibility with automated lifting devices and ground transport equipment through design features and dimensional control.

j. Suitability for loading/unloading operations on uneven terrain due to flexible floor structure.

k. Low weight potential through close attention to fabrication procedure and sequences in welding.

RECOMMENDATIONS

It is recommended that the development of the low-cost, lightweight family of gondola modules be continued as follows:

1. Complete the fabrication and testing of the two HEGS-10 modules originally included in this program and for which material is available.
2. Evaluate the HEGS-10 modules in the field.
3. Determine desired changes and improvements to both the HEGS-10 and HEGS-20 modules.
4. Optimize the design of the HEGS-10 and HEGS-20 modules.
5. Fabricate several HEGS-10 and HEGS-20 modules for user evaluation.
6. Incorporate final changes and procure both HEGS-10 and HEGS-20 modules in production quantities.

APPENDIX A
STRESS REPORT, HEGS-20 MODULE

1.0 SUMMARY

The results of the structural analyses of the HEGS-20 module are summarized in Table A-1. The critical areas, type of critical stress, and the minimum margins of safety for each component or member are shown. The margin of safety is defined as:

$$M.S. = \frac{\text{Allowable Stress or Load}}{\text{Actual Stress or Load}} - 1$$

2.0 INTRODUCTION

The loads and stresses acting on the individual members of the HEGS-20 module were determined by the use of the NASTRAN computer program developed for solving statically indeterminate structural problems, and by the use of conventional idealizations for solving statically determinate structural problems.

The NASTRAN computer program was used to analyze the complete module structure for the critical single-point suspension condition. Loads, stresses, margins of safety, and structural deformations were obtained as output from this program.

Loads and forces acting on the affected module members during the racking and stacking conditions are statically determinate; therefore, conventional stress analysis procedures were used to determine the applicable critical stresses and margins of safety for these conditions.

3.0 CONFIGURATION

Figures 5 and 6 in the main body of this report present the basic structures of the HEGS-20.

TABLE A-1. MINIMUM MARGINS OF SAFETY

MEMBER	DRAWING NUMBER	CRITICAL AREA	TYPE OF STRESS	MARGIN OF SAFETY
FLOOR STRUCTURE				
Edge Beams	KG34-004	Center Section	Yield Comp	.64
End Beams	KG34-004	Center Section	Yield Ten	.18
Longitudinal Stringers	KG34-004	Outer Stringers	Yield Ten/Comp	.78
Intermediate Laterals	KG34-004	Center Section	Yield Ten	.08
Center Beam	KG34-004	Center Section	Yield Ten	.33
SUPERSTRUCTURE				
Corner Columns	KG34-009	Center of Tube	Ult Buck	.05
Column Attach Pins	KG34-002	Pin Shank	Ult Shear	1.74
Lower Corner Fitting Lug	KG34-008	Bolt Hole	Yield Shear	.57
Center Column	KG34-010	Center of Tube	Ult Buck	1.68
Upper Sides	KG34-006	Center of Tube	Ult Buck	.17
Upper Ends	KG34-006	Ends of Tube	Ult Comp	.77
Upper Center Lateral	KG34-006	Ends of Tube	Ult Comp	6.72
Upper Diagonal Cable	KG34-014	Cable Ends	Ult Ten	3.17
Upper Diagonal Fittings	KG34-012	-15 Clevis Holes	Ult Shear	.88
Side/End Diagonal Cables	KG34-013	Cable Ends	Ult Ten	.76
Side/End Diagonal Fittings	KG34-011	-15 Clevis Holes	Ult Shear	.30
Side Diagonal Link	KG34-017	Clevis Holes	Yield Shear	.03
Upper Diagonal Attach Lugs	KG34-007	-33 Clevis Holes	Yield Shear	.33
Side/End Diagonal Attach Lug	KG34-007	-23, -31 Clevis Holes	Yield Shear	.03
Upper Diagonal Attach Pins	KG34-002	Pin Shank	Ult Shear	1.30
Side/End Diagonal Attach Pins	KG34-002	Pin Shank	Ult Shear	.93

4.0 SECTION PROPERTIES

4.1 Edge Beams - (Make From 5 x 5 x .313 5456-H111 Aluminum H-Beam)

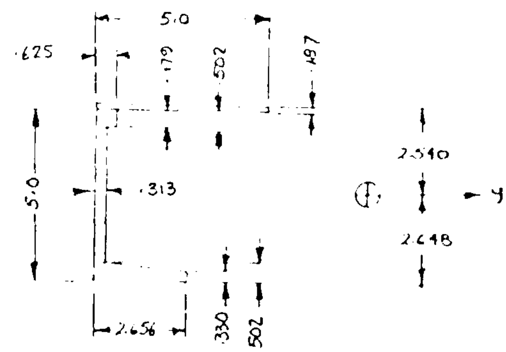
4.1.1 Edge Beam at Juncture with Lower Corner Fittings.

$A = 3.687 \text{ in.}^2$

$I_y = 15.585 \text{ in.}^4$

$J = .129 \text{ in.}^4$

$\frac{A_{WEB}}{A_{TOTAL}} = .440$



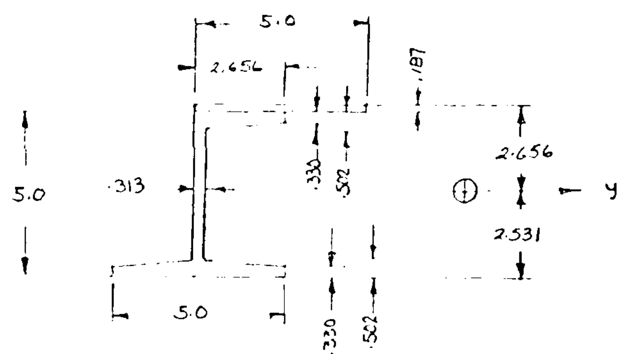
4.1.2 Edge Beam at Juncture with Center Section.

$A = 5.484 \text{ in.}^2$

$I_y = 24.986 \text{ in.}^4$

$J = .440 \text{ in.}^4$

$\frac{A_{WEB}}{A_{TOTAL}} = .296$



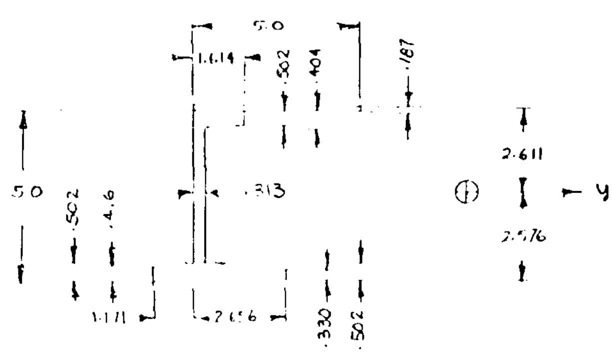
4.1.3 Edge Beam For Tapered Section.

$A = 4.614$

$I_y = 20.567$

$J = .270 \text{ in.}^4$

$\frac{A_{WEB}}{A_{TOTAL}} = .352$



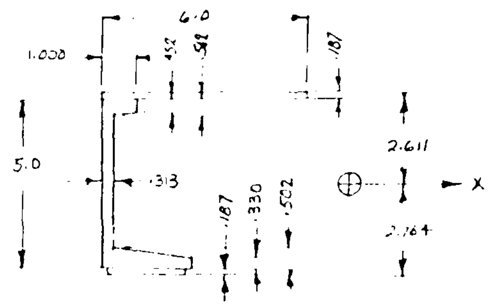
4.2 <u>End Beams (Make From 5 x 5 x .313 5456-H111 Aluminum H-Beam)</u>

$A = 4.412 \text{ in.}^2$

$I_x = 20.451 \text{ in.}^4$

$J = .327 \text{ in.}^4$

$\frac{A_{WEB}}{A_{TOTAL}} = .381$



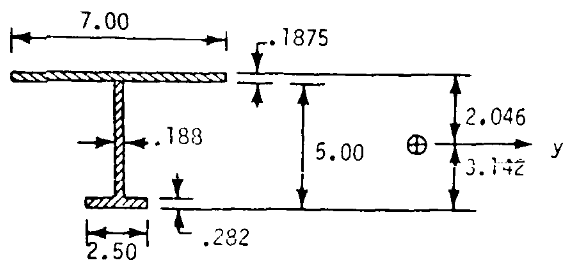
4.3 <u>Longitudinal Stringers (Make From SNAME S5 x 2.5T 5456-H111 Aluminum Tee)</u>

$A = 2.904 \text{ in.}^2$

$I_y = 13.331 \text{ in.}^4$

$J = .045 \text{ in.}^4$

$\frac{A_{WEB}}{A_{TOTAL}} = .336$



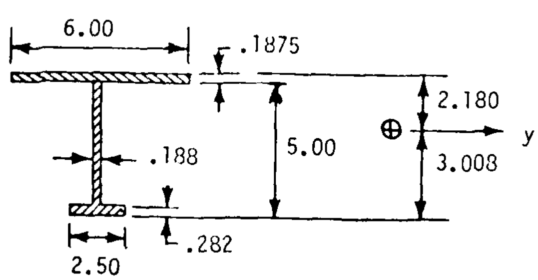
4.4 <u>Intermediate Transverse Beams (Make From SNAME S5 x 2.5T 5456-H111 Aluminum Tee)</u>

$A = 2.717 \text{ in.}^2$

$I_x = 12.563 \text{ in.}^4$

$J = .042 \text{ in.}^4$

$\frac{A_{WEB}}{A_{TOTAL}} = .359$



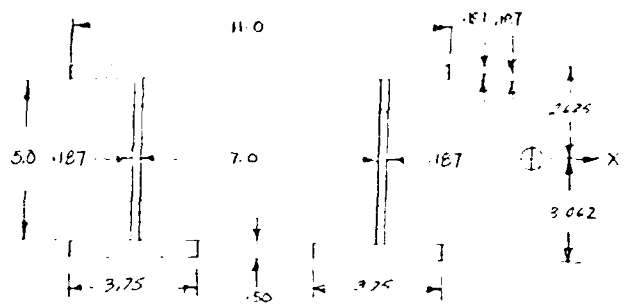
4.5 Center Beam (Make From 3/16- and 1/2-inch-thick 5456-H321 Aluminum Plate)

$A = 9.680\ \text{in.}^2$

$I_x = 61.742\ \text{in.}^4$

$J = .525\ \text{in.}^4$

$\frac{A_{WEB}}{A_{TOTAL}} = .220$

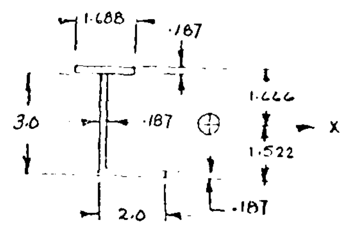


4.6 Treadway Angles (Make From 3 x 2 x 3/16 5456-H111 Aluminum Angle)

$A = 1.219\ \text{in.}^2$

$I_y = 1.899$

$\frac{A_{WEB}}{A_{TOTAL}} = .490$



4.7 Channel for Step Beams (Make From 3 x 2 6061-T6 Aluminum Channel)

$A = 1.358\ \text{in.}^2$

$W = 1.135\ \text{lb/ft.}$

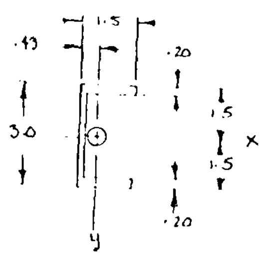
$I_x = 1.41\ \text{in.}^4$

$S_x = .94\ \text{in.}^3$

$I_y = .22\ \text{in.}^4$

$S_y = .22\ \text{in.}^3$

$r = .47\ \text{in.}$



4.8 Tube and Pipe - 6061-T6 Aluminum Alloy

SIZE	MEMBER	OD IN.	ID IN.	t IN.	A $IN.^2$	I $IN.^4$	S $IN.^3$	r IN.
3-3/4 in. d x .125 in. thick Tube	Columns	3.75	3.50	.125	1.424	2.341	1.248	1.282
5 in. Schedule 5 Pipe	Upper Structure	5.563	5.345	.109	1.88	6.96	2.50	1.924
5 in. Schedule 40 Pipe	Upper Structure	5.563	5.047	.258	4.30	15.16	5.45	1.878
4 in. Schedule 80 Pipe	Step Assembly	4.500	3.826	.337	4.407	9.611	4.272	1.477
1-1/2 in. d x .058 in. thick Tube	Step Assembly	1.50	1.384	.058	.263	.068	.091	.510

5.0 MATERIAL PROPERTIES

This section lists the material properties used in the structural analysis.

5.1 6061-T6 Aluminum Alloy (Reference 3)

		TUBING AND PLATE		FORGINGS	
		BASIC	AS WELDED	BASIC	AS WELDED
F_{tu}	(ksi)	42	24	38	24
F_{cu}	(ksi)	42	24	38	24
F_{ty}	(ksi)	35	20	35	20
F_{cy}	(ksi)	35	20	36	20
F_{su}	(ksi)	27	15	25	15
F_{sy}	(ksi)	20	12	20	12
F_{bru}	(ksi)	88	50	61 - 76	50
F_{bry}	(ksi)	56	30	54 - 61	30
E	(ksi)	10100	10100	9900	10100

5.2 5456 Aluminum Alloy (Reference 3)

		H111 EXTRUSIONS		4321 PLATE	
		BASIC	AS WELDED	BASIC	AS WELDED
F_{tu}	(ksi)	42	41	46	42
F_{cu}	(ksi)	42	41	46	42
F_{ty}	(ksi)	26	24	33	26
F_{cy}	(ksi)	22	22	27	24
F_{su}	(ksi)	25	24	27	25
F_{sy}	(ksi)	15	14	19	15
F_{bru}	(ksi)	82	82	87	84
F_{bry}	(ksi)	44	38	56	38
E	(ksi)	10400	10400	10400	10400

3. SECTION 1 SPECIFICATIONS FOR ALUMINUM STRUCTURES, The Aluminum Association, In., 750 Third Avenue, New York, New York.

5.3 17-4PH Condition H1026 Stainless Steel (Reference 4)

F_{tu}	(ksi)	155
F_{ty}	(ksi)	145
F_{su}	(ksi)	90
E	(ksi)	28500

5.4 Kevlar Diagonal Cables

5.4.1 Side/End Diagonal Cables.

58,000-POUND BREAK STRENGTH GROMMETS

Load, Lbs	Rated Break Strength	Stretch
5,800	10%	0.48%
11,600	20%	0.79%
17,400	30%	1.06%
23,200	40%	1.28%
29,000	50%	1.51%

5.4.2 Upper Diagonal Cables.

20,000-POUND BREAK STRENGTH GROMMETS

Load, Lbs	Rated Break Strength	Stretch
2,000	10%	0.45%
4,000	20%	0.74%
6,000	30%	0.96%
8,000	40%	1.22%
10,000	50%	1.50%

4. Military Standardization Handbook, METALLIC MATERIALS AND ELEMENTS FOR AEROSPACE VEHICLE STRUCTURES, MIL-HDBK-5B, U. S. Government Printing Office, Washington, D. C., 1 September 1971.

6.0 STRUCTURAL DESIGN CRITERIA

The pertinent structural design criteria applicable to the HEGS-20 are as follows:

1. Design gross weight of the loaded module shall be 25,000 pounds (1g load).
2. The design limit load factor is 2.3g.
3. The design ultimate load is 1.5 times limit load.
4. The HEGS-20 shall be compatible with the CH-47D helicopter using either the single-point sling attach system or the two-point sling attach system. The distance between the two-point attach system of the CH-47D is 13 feet. The sling angle shall not be more than 30 degrees from the vertical.
5. The floor shall be capable of sustaining loads of 300 psf (1g loading), 690 psf (design limit load), and 1035 psf (design ultimate load).
6. The distribution of the floor loading shall be 60/40 distributed longitudinally and laterally.
7. The HEGS-20 module shall be capable of being stacked two-high when loaded to the design gross weight (1g load).
8. The HEGS-20 module shall react lateral and longitudinal racking loads of 0.6g.
9. The vertical center of gravity can vary from 12 inches to 24 inches above the surface of the floor.

Figures A-1, A-2, and A-3 show the loads acting for the critical single-point suspension condition, the racking condition, and the stacking condition, respectively.

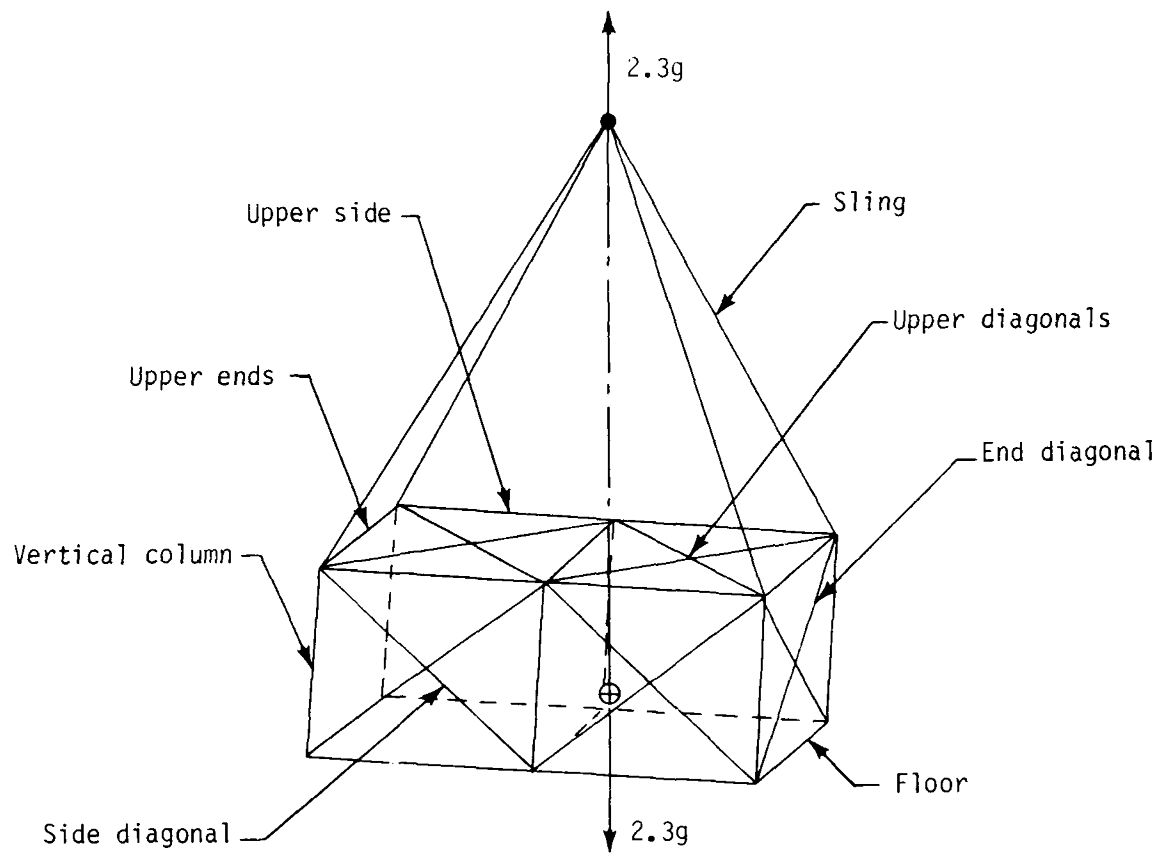
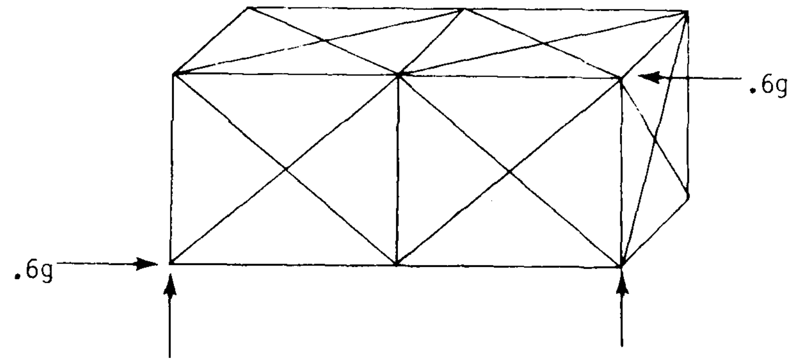
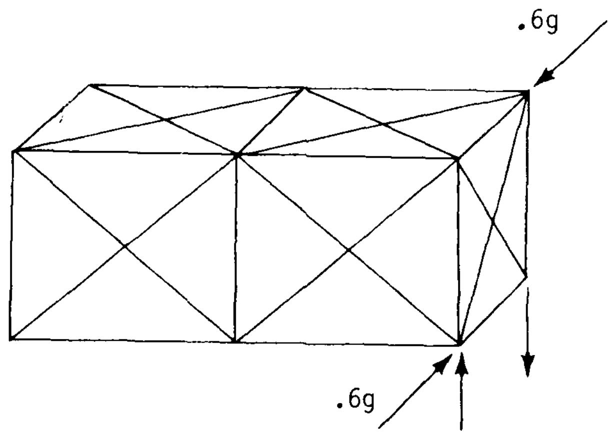


Figure A-1. HEGS-20 single-point suspension condition.



(a) Longitudinal racking.



(b) Lateral racking.

Figure A-2. HEGS-20 racking condition.

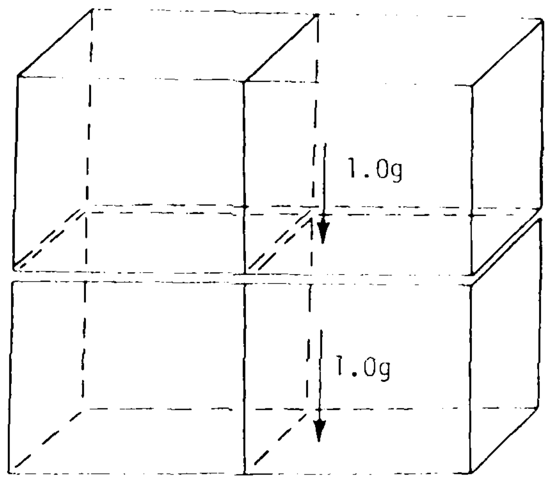


Figure A-3. HEGS-20 stacking condition.

7.0 LOADS AND STRESS ANALYSIS

The NASTRAN computer program was used to establish the limit loads, limit stresses, and margins of safety for the individual members of the HEGS-20 module when subjected to the loadings associated with the critical single-point suspension condition. Loads and stresses which develop during the racking and stacking conditions act primarily on the superstructure and are statically determinate, permitting the use of conventional analytical procedures. Thus, the structural analysis of the HEGS-20 module is divided into two segments:

1. The NASTRAN of the complete HEGS-20 module structure for the single-point suspension condition
2. The analysis of the superstructure for the single-point suspension, racking, and stacking conditions.

Superstructure loads and stresses obtained from the NASTRAN for the single-point suspension condition are also checked for buckling in the second section of these analyses.

7.1 NASTRAN for the Single-Point Suspension Condition

7.1.1 NASTRAN Model. Figures A-4, A-5, and A-6 present the NASTRAN model for the superstructure, floor grid system, and the fictitious thin sheet membrane floor elements used for analyzing the HEGS-20 module for the single-point suspension condition. Nodes, elements, and coordinates are defined in these figures. Cross sections and section properties for each member are defined in Section 4.0. Material properties are presented in Section 5.0. The allowable stresses used in the NASTRAN are based on the more critical allowable stresses, yield or ultimate, of the particular material being investigated.

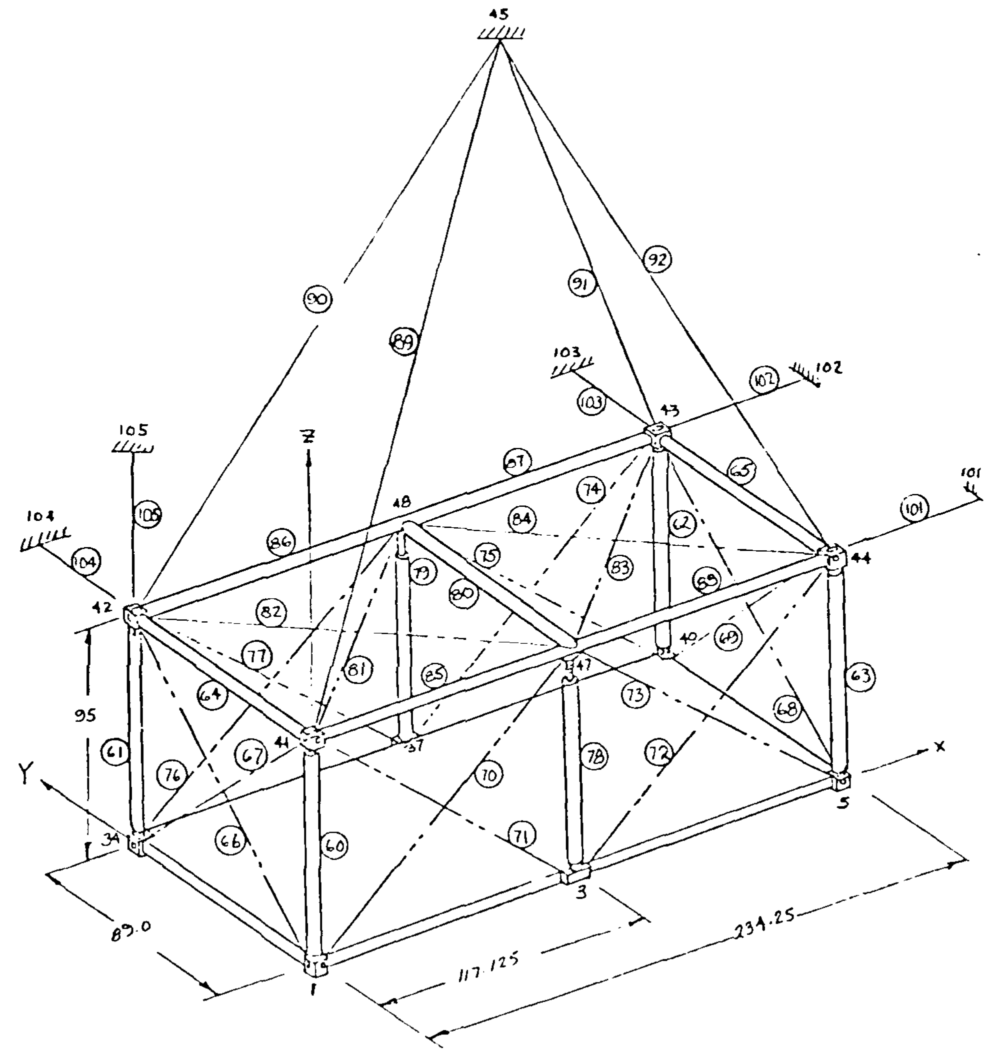


Figure A-4. NASTRAN superstructure model for single-point suspension condition - HEGS-20.

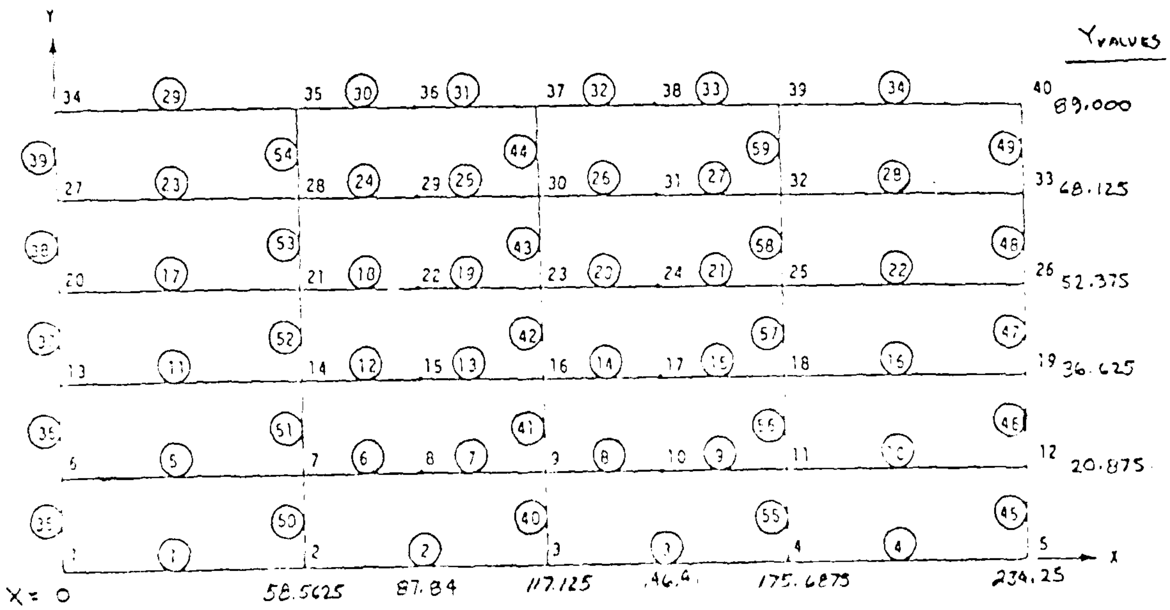


Figure A-5. NASTRAN floor beam grid model for single-point suspension condition - HEGS-20.

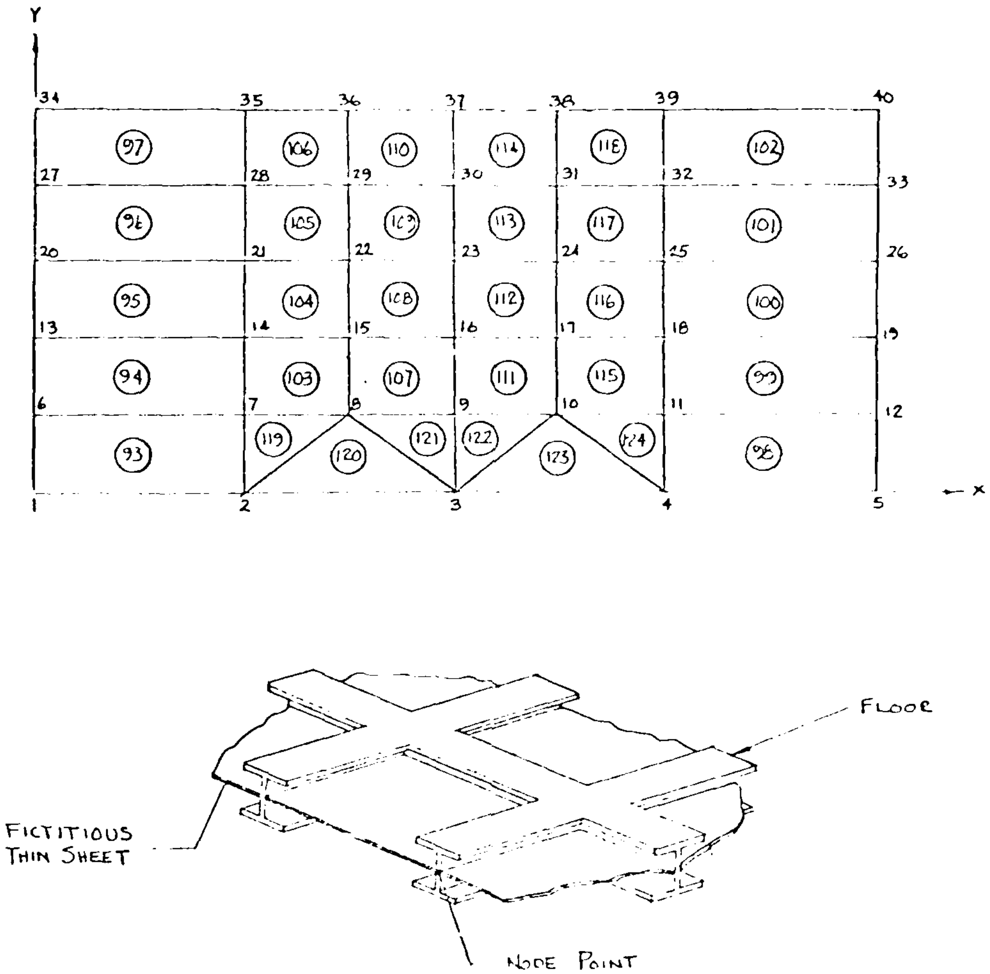


Figure A-6. NASTRAN model for floor membrane elements.

The loading applied to the floor of the HEGS-20 module for the single-point suspension condition is shown in Figure A-7. This loading represents the design gross weight of 25,000 pounds multiplied by the 2.3g design limit load factor divided by the area required to apply a design limit pressure load of 300 psi times 2.3, or 690 psf, to the floor. The resulting footprint is located on the module floor in accordance with the 60/40 longitudinal and lateral center of gravity requirement as shown in Figure A-7. The 690 psf design limit floor loading is broken down into concentrated loads acting at the applicable node points for input to the NASTRAN program.

7.1.2 NASTRAN Results. The results of the NASTRAN for the single-point suspension condition are shown on the following pages. Table A-2 presents the minimum margins of safety for the individual members of the HEGS-20 module for this condition.

TABLE A-2. MINIMUM MARGINS OF SAFETY FOR THE SINGLE-POINT SUSPENSION CONDITION

MEMBER	ELEMENT NUMBER	MARGIN OF SAFETY
FLOOR ASSEMBLY		
Edge Beams, End Sections	4	1.7
Edge Beams, Center Sections	33	.64
End Beams	47, 48	.18
Longitudinal Stringers	27, 28	.78
Intermediate Transverse Beams	57, 58	.08
Center Beam	42, 43	.33
SUPERSTRUCTURE		
Corner Columns	62	1.7
Center Columns	78, 79	Ample
Upper Side Members	86	.29
Upper End Members	65	6.3
Upper Center Transverse Member	80	160.0
End Diagonals	69	32.0
Side Diagonals	77	1.7
Upper Diagonals	83	220.0

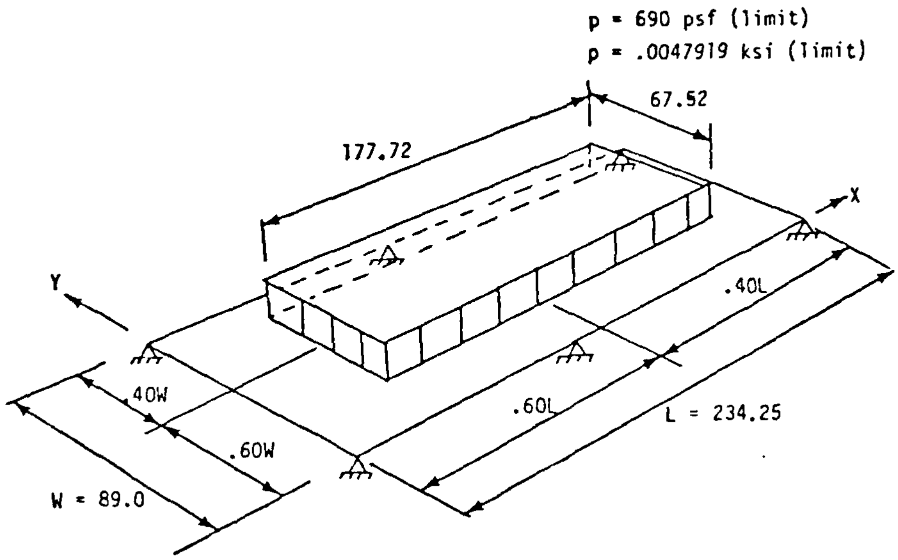


Figure A-7. Limit floor loading for the HEGS-20 module.

```
N A S T R A N   E X E C U T I V E   C O N T R O L   D E C K   E C H O

ID KAMAN, GONDOLA
SOL 24
TIME 5
DIAG 8,13,16
CEND


HEGS-20 GONDOLA ASSEMBLY

                         C A S E   C O N T R O L   D E C K   E C H O
CARD
COUNT
  1      TITLE = HEGS-20 GONDOLA ASSEMBLY
  2      SUBCASE 1
  3          SUBTITLE = RUN 1.01, 1-POINT, LIMIT LOAD, 60-40 DIST., 690 PSF
  4          LOAD = 201
  5          TEMPERATURE(LOAD) = 101
  6          DISP = ALL
  7          ELFO = ALL
  8          STRESS = ALL
  9          OLOAD = ALL
 10          SPCFORCES = ALL
 11      BEGIN BULK

         TOTAL COUNT=  296
```

HEGS-20 GONDOLA ASSEMBLY

S O R T E D   B U L K   D A T A   E C H O

CARD COUNT	. 1 ..	2 ..	3 ..	4 ..	5 ..	6 ..	7 ..	8 ..	9 ..	10 .
1-	CBAR	1	7	1	2	6			2	
2-	CBAR	2	1	2	3	7			2	
3-	CBAR	3	1	3	4	9			2	
4-	CBAR	4	7	4	5	11			2	
5-	CBAR	5	2	6	7	13			2	BC51
6-	+C51	5								
7-	CBAR	6	2	7	8	14			2	
8-	CBAR	7	2	8	9	15			2	
9-	CBAR	8	2	9	10	16			2	
10-	CBAR	9	2	10	11	17			2	
11-	CBAR	10	2	11	12	18			2	BC101
12-	+C101		5							
13-	CBAR	11	2	13	14	20			2	BC111
14-	+C111		5							
15-	CBAR	12	2	14	15	21			2	
16-	CBAR	13	2	15	16	22			2	
17-	CBAR	14	2	16	17	23			2	
18-	CBAR	15	2	17	18	24			2	
19-	CBAR	16	2	18	19	25			2	BC161
20-	+C161		5							
21-	CBAR	17	2	20	21	27			2	BC171
22-	+C171	5								
23-	CBAR	18	2	21	22	28			2	
24-	CBAR	19	2	22	23	29			2	
25-	CBAR	20	2	23	24	30			2	
26-	CBAR	21	2	24	25	31			2	
27-	CBAR	22	2	25	26	32			2	BC221
28-	+C221		5							
29-	CBAR	23	2	27	28	34			2	BC231
30-	+C231	5								
31-	CBAR	24	2	28	29	35			2	
32-	CBAR	25	2	29	30	36			2	
33-	CBAR	26	2	30	31	37			2	
34-	CBAR	27	2	31	32	38			2	
35-	CBAR	28	2	32	33	39			2	BC281
36-	+C281		5							
37-	CBAR	29	7	34	35	200.	200.	.0	1	
38-	CBAR	30	1	35	36	200.	200.	.0	1	
39-	CBAR	31	1	36	37	200.	200.	.0	1	
40-	CBAR	32	1	37	38	200.	200.	.0	1	
41-	CBAR	33	1	38	39	200.	200.	.0	1	
42-	CBAR	34	7	39	40	200.	200.	.0	1	
43-	CBAR	35	3	1	6	-100.	200.	.0	1	
44-	CBAR	36	3	6	13	-100.	200.	.0	1	
45-	CBAR	37	3	13	20	-100.	200.	.0	1	
46-	CBAR	38	3	20	27	-100.	200.	.0	1	
47-	CBAR	39	3	27	34	-100.	200.	.0	1	
48-	CBAR	40	5	3	9	1			2	
49-	CBAR	41	5	9	16	6			2	
50-	CBAR	42	5	16	23	13			2	

HEGS-20 GONDOLA ASSEMBLY

SORTED BULK DATA ECHO

CARD COUNT	. 1 ..	2 ..	3 ..	4 ..	5 ..	6 ..	7 ..	8 ..	9 ..	10
51-	CBAR	43	5	23	30	20			2	
52-	CBAR	44	5	30	37	27			2	
53-	CBAR	45	3	5	12	3			2	
54-	CBAR	46	3	12	19	9			2	
55-	CBAR	47	3	19	26	16			2	
56-	CBAR	48	3	26	33	23			2	
57-	CBAR	49	3	33	40	30			2	
58-	CBAR	50	4	2	7	1			2	
59-	CBAR	51	4	7	14	6			2	
60-	CBAR	52	4	14	21	13			2	
61-	CBAR	53	4	21	28	20			2	
62-	CBAR	54	4	28	35	27			2	
63-	CBAR	55	4	4	11	3			2	
64-	CBAR	56	4	11	18	9			2	
65-	CBAR	57	4	18	25	16			2	
66-	CBAR	58	4	25	32	23			2	
67-	CBAR	59	4	32	39	30			2	
68-	CBAR	64	6	41	42	-100.	200.	95.0	1	
69-	CBAR	65	6	44	43	47			2	
70-	CBAR	80	6	47	48	41			2	
71-	CBAR	85	6	41	47	42			2	
72-	CBAR	86	6	42	48	200.	200.	95.0	1	
73-	CBAR	87	6	48	43	200.	200.	95.0	1	
74-	CBAR	88	6	47	44	48			2	
75-	CONROD	60	1	41	2	1.424				
76-	CONROD	61	34	42	2	1.424				
77-	CONROD	62	40	43	2	1.424				
78-	CONROD	63	5	44	2	1.424				
79-	CONROD	66	1	42	6	.5				
80-	CONROD	67	34	41	4	.5				
81-	CONROD	68	5	43	6	.5				
82-	CONROD	69	40	44	4	.5				
83-	CONROD	70	1	47	6	.5				
84-	CONROD	71	3	41	4	.5				
85-	CONROD	72	3	44	4	.5				
86-	CONROD	73	5	47	6	.5				
87-	CONROD	74	37	43	4	.5				
88-	CONROD	75	40	48	6	.5				
89-	CONROD	76	34	48	6	.5				
90-	CONROD	77	37	42	4	.5				
91-	CONROD	78	3	47	7	1.424				
92-	CONROD	79	37	48	7	1.424				
93-	CONROD	81	41	48	5	.5				
94-	CONROD	82	42	47	5	.5				
95-	CONROD	83	43	47	5	.5				
96-	CONROD	84	44	48	5	.5				
97-	CONROD	89	41	45	4	.5				
98-	CONROD	90	42	45	4	.5				
99-	CONROD	91	43	45	4	.5				
100-	CONROD	92	44	45	4	.5				

MEGS-20 GONDOLA ASSEMBLY

S O R T E D   B U L K   D A T A   E C H O

CARD COUNT	. 1 ..	2 ..	3 ..	4 ..	5 ..	6 ..	7 ..	8 ..	9 ..	10
101-	CQUAD4	93	1	1	2	7	6	.0		
102-	CQUAD4	94	1	6	7	14	13	.0		
103-	CQUAD4	95	1	13	14	21	20	.0		
104-	CQUAD4	96	1	20	21	28	27	.0		
105-	CQUAD4	97	1	27	28	35	34	.0		
106-	CQUAD4	98	1	4	5	12	11	.0		
107-	CQUAD4	99	1	11	12	19	18	.0		
108-	CQUAD4	100	1	18	19	26	25	.0		
109-	CQUAD4	101	1	25	26	33	32	.0		
110-	CQUAD4	102	1	32	33	40	39	.0		
111-	CQUAD4	103	1	7	8	15	14	.0		
112-	CQUAD4	104	1	14	15	22	21	.0		
113-	CQUAD4	105	1	21	22	29	28	.0		
114-	CQUAD4	106	1	28	29	36	35	.0		
115-	CQUAD4	107	1	8	9	16	15	.0		
116-	CQUAD4	108	1	15	16	23	22	.0		
117-	CQUAD4	109	1	22	23	30	29	.0		
118-	CQUAD4	110	1	29	30	37	36	.0		
119-	CQUAD4	111	1	9	10	17	16	.0		
120-	CQUAD4	112	1	16	17	24	23	.0		
121-	CQUAD4	113	1	23	24	31	30	.0		
122-	CQUAD4	114	1	30	31	38	37	.0		
123-	CQUAD4	115	1	10	11	18	17	.0		
124-	CQUAD4	116	1	17	18	25	24	.0		
125-	CQUAD4	117	1	24	25	32	31	.0		
126-	CQUAD4	118	1	31	32	39	38	.0		
127-	CTRIA3	119	1	8	7	2	.0			
128-	CTRIA3	120	1	2	3	8	.0			
129-	CTRIA3	121	1	9	8	3	.0			
130-	CTRIA3	122	1	10	9	3	.0			
131-	CTRIA3	123	1	3	4	10	.0			
132-	CTRIA3	124	1	11	10	4	.0			
133-	FORCE	201	1		.0	.081	.031	.0		
134-	FORCE	201	2		.001	.081	.031	.0		
135-	FORCE	201	3		.002	.081	.031	.0		
136-	FORCE	201	4		.002	.081	.031	.0		
137-	FORCE	201	5		.001	.081	.031	.0		
138-	FORCE	201	6		.008	.081	.031	.0		
139-	FORCE	201	7		.776	.081	.031	.0		
140-	FORCE	201	8		1.174	.081	.031	.0		
141-	FORCE	201	9		1.174	.081	.031	.0		
142-	FORCE	201	10		1.174	.081	.031	.0		
143-	FORCE	201	11		1.758	.081	.031	.0		
144-	FORCE	201	12		1.061	.081	.031	.0		
145-	FORCE	201	13		.016	.081	.031	.0		
146-	FORCE	201	14		1.461	.081	.031	.0		
147-	FORCE	201	15		2.210	.081	.031	.0		
148-	FORCE	201	16		2.210	.081	.031	.0		
149-	FORCE	201	17		2.210	.081	.031	.0		
150-	FORCE	201	18		3.310	.081	.031	.0		

HEGS-20 GONDOLA ASSEMBLY

SORTED BULK DATA ECHO

CARD COUNT	. 1 ..	2 ..	3 ..	4 ..	5 ..	6 ..	7 ..	8 ..	9 ..	10
151-	FORCE	201	19		1.997	.081	.031	.0		
152-	FORCE	201	20		.016	.081	.031	.0		
153-	FORCE	201	21		1.461	.081	.031	.0		
154-	FORCE	201	22		2.210	.081	.031	.0		
155-	FORCE	201	23		2.210	.081	.031	.0		
156-	FORCE	201	24		2.210	.081	.031	.0		
157-	FORCE	201	25		3.310	.081	.031	.0		
158-	FORCE	201	26		1.997	.081	.031	.0		
159-	FORCE	201	27		.015	.081	.031	.0		
160-	FORCE	201	28		1.696	.081	.031	.0		
161-	FORCE	201	29		2.565	.081	.031	.0		
162-	FORCE	201	30		2.565	.081	.031	.0		
163-	FORCE	201	31		2.565	.081	.031	.0		
164-	FORCE	201	32		3.612	.081	.031	.0		
165-	FORCE	201	33		2.319	.081	.031	.0		
166-	FORCE	201	34		.001	.081	.031	.0		
167-	FORCE	201	35		.869	.081	.031	.0		
168-	FORCE	201	36		1.314	.081	.031	.0		
169-	FORCE	201	37		1.314	.081	.031	.0		
170-	FORCE	201	38		1.314	.081	.031	.0		
171-	FORCE	201	39		1.968	.081	.031	.0		
172-	FORCE	201	40		1.188	.081	.031	.0		
173-	FORCE	201	45		1.	-4.658	-1.782	57.283		
174-	GRID	1		.0	.0	.0				
175-	GRID	2		58.56	.0	.0				
176-	GRID	3		117.12	.0	.0				
177-	GRID	4		175.69	.0	.0				
178-	GRID	5		234.25	.0	.0				
179-	GRID	6		.0	20.88	.0				
180-	GRID	7		58.56	20.88	.0				
181-	GRID	8		87.84	20.88	.0				
182-	GRID	9		117.12	20.88	.0				
183-	GRID	10		146.41	20.88	.0				
184-	GRID	11		175.69	20.88	.0				
185-	GRID	12		234.25	20.88	.0				
186-	GRID	13		.0	36.63	.0				
187-	GRID	14		58.56	36.63	.0				
188-	GRID	15		87.84	36.63	.0				
189-	GRID	16		117.12	36.63	.0				
190-	GRID	17		146.41	36.63	.0				
191-	GRID	18		175.69	36.63	.0				
192-	GRID	19		234.25	36.63	.0				
193-	GRID	20		.0	52.38	.0				
194-	GRID	21		58.56	52.38	.0				
195-	GRID	22		87.84	52.38	.0				
196-	GRID	23		117.12	52.38	.0				
197-	GRID	24		146.41	52.38	.0				
198-	GRID	25		175.69	52.38	.0				
199-	GRID	26		234.25	52.38	.0				
200-	GRID	27		.0	68.13	.0				

9
B

HEGS-20 GONDOLA ASSEMBLY

S O R T E D   B U L K   D A T A   E C H O

CARD COUNT	. 1 ..	2 ..	3 ..	4 ..	5 ..	6 ..	7 ..	8 ..	9 ..	10 .
201-	GRID	28		58.56	68.13	.0				
202-	GRID	29		87.84	68.13	.0				
203-	GRID	30		117.12	68.13	.0				
204-	GRID	31		146.41	68.13	.0				
205-	GRID	32		175.69	68.13	.0				
206-	GRID	33		234.25	68.13	.0				
207-	GRID	34		.0	89.0	.0				
208-	GRID	35		58.56	89.0	.0				
209-	GRID	36		87.84	89.0	.0				
210-	GRID	37		117.12	89.0	.0				
211-	GRID	38		146.41	89.0	.0				
212-	GRID	39		175.69	89.0	.0				
213-	GRID	40		234.25	89.0	.0				
214-	GRID	41		.0	.0	95.0		123		
215-	GRID	42		.0	89.0	95.0		3		
216-	GRID	43		234.25	89.0	95.0				
217-	GRID	44		234.25	.0	95.0		23		
218-	GRID	45		117.12	44.5	312.02		456		
219-	GRID	47		117.12	.0	95.0				
220-	GRID	48		117.12	89.0	95.0				
221-	MAT1	1	10400.	4000.						MA11
222-	+A11	26.	27.	14.						
223-	MAT1	2	10100.	4000.						MA21
224-	+A21	16.	16.	10.0						
225-	MAT1	3	10100.	4000.						MA31
226-	+A31	16.	16.	14.						
227-	MAT1	4	8000.		.3					MA41
228-	+A41	108.	10.	10.						
229-	MAT1	5	4000.		.3		.00001			MA51
230-	+A51	108.	10.	10.						
231-	MAT1	6	1.		.3					MA61
232-	+A61	108.	10.	10.						
233-	MAT1	7	.1	.1						MA71
234-	+A71	16.	16.	10.						
235-	PBAR	1	1	5.484	1.	24.986	.440			PB11
236-	+B11	.0	2.656	.0	-2.531					PB12
237-	+B12	.296	.296							
238-	PBAR	2	1	2.904	1.	13.331	.045			PB21
239-	+B21	.0	2.406	.0	-3.142					PB22
240-	+B22	.336	.336							
241-	PBAR	3	1	4.412	1.	20.451	.327			PB31
242-	+B31	.0	2.611	.0	-2.764					PB32
243-	+B32	.381	.381							
244-	PBAR	4	1	2.717	1.	12.563	.042			PB41
245-	+B41	.0	2.18	.0	-3.008					PB42
246-	+B42	.359	.359							
247-	PBAR	5	1	9.68	1.	61.742	.525			PB51
248-	+B51	.0	2.625	.0	-3.062					PB52
249-	+B52	.220	.220							
250-	PBAR	6	2	1.88	1.	6.96	13.92			PB61

HEUS-20 GONDOLA ASSEMBLY

SORTED BULK DATA ECHO

CARD COUNT	1	2	3	4	5	6	7	8	9	10
251-	+H61	.0	2.782	.0	-2.782					PH62
252-	+H62	.5	.5							
253-	PBAR	7	1	4.614	1.	20.567	.27			PB71
254-	+B71	.0	2.611	.0	-2.576					PB72
255-	+B72	.352	.352							
256-	PLOAD1	201	2	FZ	FR	.0	-.00003	1.	-.00003	
257-	PLOAD1	201	3	FZ	FR	.0	-.00003	1.	-.00003	
258-	PLOAD1	201	4	FZ	FR	.0	-.00003	.951	-.00003	
259-	PLOAD1	201	5	FZ	FR	.916	-.03996	1.	-.03996	
260-	PLOAD1	201	6	FZ	FR	.0	-.03996	1.	-.03996	
261-	PLOAD1	201	7	FZ	FR	.0	-.03996	1.	-.03996	
262-	PLOAD1	201	8	FZ	FR	.0	-.03996	1.	-.03996	
263-	PLOAD1	201	9	FZ	FR	.0	-.03996	1.	-.03996	
264-	PLOAD1	201	10	FZ	FR	.0	-.03996	.951	-.03996	
265-	PLOAD1	201	11	FZ	FR	.916	-.0752	1.	-.0752	
266-	PLOAD1	201	12	FZ	FR	.0	-.0752	1.	-.0752	
267-	PLOAD1	201	13	FZ	FR	.0	-.0752	1.	-.0752	
268-	PLOAD1	201	14	FZ	FR	.0	-.0752	1.	-.0752	
269-	PLOAD1	201	15	FZ	FR	.0	-.0752	1.	-.0752	
270-	PLOAD1	201	16	FZ	FR	.0	-.0752	.951	-.0752	
271-	PLOAD1	201	17	FZ	FR	.916	-.0752	1.	-.0752	
272-	PLOAD1	201	18	FZ	FR	.0	-.0752	1.	-.0752	
273-	PLOAD1	201	19	FZ	FR	.0	-.0752	1.	-.0752	
274-	PLOAD1	201	20	FZ	FR	.0	-.0752	1.	-.0752	
275-	PLOAD1	201	21	FZ	FR	.0	-.0752	1.	-.0752	
276-	PLOAD1	201	22	FZ	FR	.0	-.0752	.951	-.0752	
277-	PLOAD1	201	23	FZ	FR	.916	-.0873	1.	-.0873	
278-	PLOAD1	201	24	FZ	FR	.0	-.0873	1.	-.0873	
279-	PLOAD1	201	25	FZ	FR	.0	-.0873	1.	-.0873	
280-	PLOAD1	201	26	FZ	FR	.0	-.0873	1.	-.0873	
281-	PLOAD1	201	27	FZ	FR	.0	-.0873	1.	-.0873	
282-	PLOAD1	201	28	FZ	FR	.0	-.0873	.951	-.0873	
283-	PLOAD1	201	29	FZ	FR	.916	-.0447	1.	-.0447	
284-	PLOAD1	201	30	FZ	FR	.0	-.0447	1.	-.0447	
285-	PLOAD1	201	31	FZ	FR	.0	-.0447	1.	-.0447	
286-	PLOAD1	201	32	FZ	FR	.0	-.0447	1.	-.0447	
287-	PLOAD1	201	33	FZ	FR	.0	-.0447	1.	-.0447	
288-	PLOAD1	201	34	FZ	FR	.0	-.0447	.951	-.0447	
289-	PQUAD4	1	1	.04						
290-	PSHELL	1	1	.04						
291-	TEMPD	101								
292-	TEMPRB	101	81	-150.						
293-	TEMPRB	101	82	-150.						
294-	TEMPRB	101	83	-150.						
295-	TEMPRB	101	84	-150.						
	ENDDATA									

TOTAL COUNT= 295

HESS-20 GONDOLA ASSEMBLY
RUN 1.01, 1-POINT, LIMIT LOAD, 60-40 DIST., 690 PSF

SUBCASE 1

D I S P L A C E M E N T   V E C T O R

POINT ID.	TYPE	T1	T2	T3	R1	R2	R3
1	G	-3.998800E-02	3.705965E-02	-1.028168E-02	-3.194140E-03	1.244482E-02	-2.969918E-04
2	G	-4.035854E-02	2.213233E-02	-6.251342E-01	-1.644590E-02	6.283357E-03	-3.016553E-04
3	G	-4.139361E-02	5.607138E-03	-8.056739E-01	-2.230749E-02	2.157429E-03	-3.528383E-04
4	G	-4.151391E-02	-1.412946E-02	-6.087919E-01	-2.838123E-02	-5.741359E-03	-3.699150E-04
5	G	-4.135144E-02	-3.656167E-02	-4.241646E-02	-2.204559E-02	-1.645905E-02	-3.831930E-04
6	G	-3.332632E-02	3.702800E-02	-7.352554E-02	-2.355130E-03	1.545426E-02	-3.151662E-04
7	G	-3.331305E-02	2.211866E-02	-9.582565E-01	-1.367630E-02	1.066304E-02	-3.212251E-04
8	G	-3.335736E-02	1.412648E-02	-1.175631E+00	-1.594032E-02	4.659833E-03	-2.546745E-04
9	G	-3.343227E-02	5.601505E-03	-1.272520E+00	-1.820435E-02	4.234211E-03	-3.555244E-04
10	G	-3.343406E-02	-4.110674E-03	-1.416743E+00	-2.098171E-02	2.643167E-03	-3.246330E-04
11	G	-3.347757E-02	-1.411155E-02	-1.384304E+00	-2.375013E-02	-6.013445E-03	-3.667545E-04
12	G	-3.348969E-02	-3.666410E-02	-4.821036E-01	-1.681617E-02	-2.015172E-02	-3.739981E-04
13	G	-2.801515E-02	3.692834E-02	-1.000500E-01	-9.495991E-04	1.777694E-02	-3.092208E-04
14	G	-2.801191E-02	2.210264E-02	-1.139040E+00	-7.850080E-03	8.996730E-03	-3.066793E-04
15	G	-2.797138E-02	1.410595E-02	-1.372504E+00	-9.194387E-03	6.050164E-03	-2.644335E-04
16	G	-2.793576E-02	5.501206E-03	-1.516870E+00	-1.053869E-02	6.313374E-03	-3.280925E-04
17	G	-2.787441E-02	-3.923401E-03	-1.724901E+00	-1.246324E-02	4.162647E-03	-3.351626E-04
18	G	-2.786512E-02	-1.407984E-02	-1.701023E+00	-1.438713E-02	-6.125639E-03	-3.475373E-04
19	G	-2.785018E-02	-3.669924E-02	-6.825777E-01	-7.061946E-03	-2.292960E-02	-3.483255E-04
20	G	-2.341892E-02	3.677943E-02	-1.030493E-01	7.635960E-04	1.843543E-02	-2.573330E-04
21	G	-2.320998E-02	2.208440E-02	-1.204206E+00	-6.816644E-04	1.372588E-02	-2.859003E-04
22	G	-2.304975E-02	1.417132E-02	-1.468259E+00	-9.043763E-04	5.906347E-03	-2.749765E-04
23	G	-2.291538E-02	5.602247E-03	-1.612035E+00	-1.126672E-03	6.175581E-03	-3.038845E-04
24	G	-2.282106E-02	-3.789591E-03	-1.845062E+00	-1.794606E-03	5.119324E-03	-3.456604E-04
25	G	-2.275917E-02	-1.404420E-02	-1.835040E+00	-2.462630E-03	-6.419633E-03	-3.725145E-04
26	G	-2.270340E-02	-3.678220E-02	-7.019274E-01	4.813881E-03	-2.570748E-02	-3.229475E-04
27	G	-1.902038E-02	3.659947E-02	-7.561732E-02	2.422487E-03	1.904392E-02	-2.539122E-04
28	G	-1.881198E-02	2.207166E-02	-1.161757E+00	5.246276E-03	1.352001E-02	-2.594197E-04
29	G	-1.864313E-02	1.410743E-02	-1.437531E+00	6.323555E-03	5.515498E-03	-2.915074E-04
30	G	-1.845003E-02	5.602165E-03	-1.546536E+00	7.398834E-03	6.209516E-03	-2.603340E-04
31	G	-1.826317E-02	-3.655247E-03	-1.793187E+00	7.807887E-03	5.412825E-03	-3.599718E-04
32	G	-1.807855E-02	-1.401041E-02	-1.779866E+00	8.216801E-03	-7.076581E-03	-3.060875E-04
33	G	-1.790750E-02	-3.693473E-02	-5.324600E-01	1.544850E-02	-2.645530E-02	-3.108625E-04
34	G	-1.371903E-02	3.634205E-02	-9.692931E-03	3.391989E-03	1.996640E-02	-2.475553E-04
35	G	-1.369532E-02	2.207683E-02	-9.956472E-01	8.553634E-03	1.000260E-02	-2.471814E-04
36	G	-1.375457E-02	1.406449E-02	-1.182554E+00	1.041762E-02	4.145740E-03	-2.971581E-04
37	G	-1.397044E-02	5.598727E-03	-1.290923E+00	1.228041E-02	5.760861E-03	-2.514435E-04
38	G	-1.301972E-02	-3.763060E-03	-1.503782E+00	1.331335E-02	5.075589E-03	-3.560718E-04
39	G	-1.231019E-02	-1.398431E-02	-1.533504E+00	1.434595E-02	-7.668043E-03	-3.207919E-04
40	G	-1.161822E-02	-3.729378E-02	-1.073954E-01	2.150169E-02	-3.216627E-02	-3.342117E-04
41	G	0.0	0.0	0.0	-6.859147E-05	1.797782E-04	-7.049777E-04
42	G	5.578527E-02	-1.360177E-02	0.0	3.893463E-06	4.024152E-04	-5.663257E-04
43	G	-2.267568E-01	-1.879358E-02	-5.090195E-02	-5.455347E-04	7.343772E-06	3.427409E-04
44	G	-1.922647E-01	0.0	0.0	-5.468279E-04	-9.694224E-05	4.527331E-04
45	G	-4.000897E-01	-8.924934E-01	1.249613E+00	0.0	0.0	0.0
47	G	-9.560808E-02	-3.845131E-02	-9.718344E-03	-3.143514E-04	6.143366E-06	-3.344897E-05
48	G	-8.460109E-02	-3.923222E-02	-3.738273E-02	-3.001147E-04	2.040197E-04	-6.679727E-06

HEGS-20 GONDOLA ASSEMBLY
RUN 1.01, 1-POINT, LIMIT LOAD, 60-40 DIST., 690 PSF

SUBCASE 1

L O A D   V E C T O R

POINT ID.	TYPE	T1	T2	T3	R1	R2	R3
2	G	8.100000E-05	3.100000E-05	-8.784[illegible]E-04	0.0	8.573164E-03	0.0
3	G	1.620000E-04	6.200000E-05	-1.756955E-03	0.0	2.926250E-06	0.0
4	G	1.620000E-04	6.200000E-05	-1.756951E-03	0.0	-1.258430E-05	0.0
5	G	8.100000E-05	3.100000E-05	-7.927155E-04	0.0	-6.463369E-03	0.0
6	G	6.480000E-04	2.480000E-04	-9.072750E-04	0.0	0.0	0.0
7	G	6.285000E-02	2.405000E-02	-7.806720E-01	0.0	2.424545E+00	0.0
8	G	9.507400E-02	3.639400E-02	-1.170224E+00	0.0	4.263256E-14	0.0
9	G	9.509400E-02	3.639400E-02	-1.170224E+00	0.0	1.956941E-03	0.0
10	G	9.507400E-02	3.639400E-02	-1.170224E+00	0.0	-1.950591E-03	0.0
11	G	1.423780E-01	5.449000E-02	-2.045556E+00	0.0	1.307641E+01	0.0
12	G	8.594100E-02	3.289100E-02	-7.759430E-01	0.0	0.0	0.0
13	G	1.296000E-03	4.960000E-04	-2.304174E-02	0.0	4.376159E-01	0.0
14	G	1.104100E-01	4.524100E-02	-1.447796E+00	0.0	5.372529E+00	0.0
15	G	1.790100E-01	6.851000E-02	-2.201856E+00	0.0	8.526513E-14	0.0
16	G	1.790100E-01	6.851000E-02	-2.202232E+00	0.0	3.570387E-03	0.0
17	G	1.790100E-01	6.851000E-02	-2.202232E+00	0.0	-3.670387E-03	0.0
18	G	2.661100E-01	1.026100E-01	-3.828810E+00	0.0	2.574116E+01	0.0
19	G	1.617570E-01	6.190700E-02	-1.450[illegible]E+00	0.0	0.0	0.0
20	G	1.296000E-03	4.960000E-04	-1.737384E-03	0.0	0.0	0.0
21	G	1.183410E-01	4.529100E-02	-1.459132E+00	0.0	4.562706E+00	0.0
22	G	1.790100E-01	6.851000E-02	-2.201856E+00	0.0	8.526513E-14	0.0
23	G	1.790100E-01	6.851000E-02	-2.202232E+00	0.0	3.570387E-03	0.0
24	G	1.790100E-01	6.851000E-02	-2.202232E+00	0.0	-3.670387E-03	0.0
25	G	2.661100E-01	1.026100E-01	-3.828810E+00	0.0	2.574116E+01	0.0
26	G	1.617570E-01	6.190700E-02	-1.460[illegible]E+00	0.0	0.0	0.0
27	G	1.458000E-03	5.580000E-04	-1.922110E-03	0.0	0.0	0.0
28	G	1.373700E-01	5.257000E-02	-1.785522E+00	0.0	5.295867E+00	0.0
29	G	2.077650E-01	7.951500E-02	-2.556194E+00	0.0	1.136868E-13	0.0
30	G	2.077650E-01	7.951500E-02	-2.556591E+00	0.0	4.253967E-03	0.0
31	G	2.077650E-01	7.951500E-02	-2.556591E+00	0.0	-4.250968E-03	0.0
32	G	3.097720E-01	1.191720E-01	-4.444852E+00	0.0	2.988302E+01	0.0
33	G	1.878[illegible]E-01	7.188910E-02	-1.594976E+00	0.0	0.0	0.0
34	G	8.100000E-05	3.100000E-05	-2.286641E-03	0.0	5.181624E-02	0.0
35	G	7.038[illegible]E-02	2.693900E-02	-8.720022E-01	0.0	2.734810E+00	0.0
36	G	1.064340E-01	4.073400E-02	-1.308816E+00	0.0	5.684342E-14	0.0
37	G	1.064340E-01	4.073400E-02	-1.309043E+00	0.0	2.181732E-03	0.0
38	G	1.064340E-01	4.073400E-02	-1.309043E+00	0.0	-2.181733E-03	0.0
39	G	1.574[illegible]E-01	6.100900E-02	-1.952530E+00	0.0	4.506146E+00	0.0
40	G	9.622600E-02	3.682800E-02	-1.161146E+00	0.0	-1.261042E+01	0.0
41	G	1.194298E+00	9.075525E-01	0.0	0.0	0.0	0.0
42	G	1.194298E+00	-9.075525E-01	0.0	0.0	0.0	0.0
43	G	-1.194336E+00	-9.075034E-01	0.0	0.0	0.0	0.0
44	G	-1.194336E+00	9.075034E-01	0.0	0.0	0.0	0.0
45	G	-4.658000E+00	-1.782000E+00	5.728300E+01	0.0	0.0	0.0
47	G	3.732566E-05	1.815056E+00	0.0	0.0	0.0	0.0
48	G	3.732566E-05	-1.815056E+00	0.0	0.0	0.0	0.0

F O R C E S   O F   S I N G L E - P O I N T   C O N S T R A I N T

POINT ID.	TYPE	T1	T2	T3	R1	R2	R3
41	G	3.173000E-03	2.561091E-03	3.275693E-02	0.0	0.0	0.0
42	G	0.0	0.0	-3.148935E-02	0.0	0.0	0.0
44	G	0.0	-2.038091E-03	1.735453E-02	0.0	0.0	0.0

MEGS-20 GONDOLA ASSEMBLY
RUN 1.LI, 1-POINT, LIMIT LOAD, 60-40 DIST., 690 PSF

SUBCASE 1

F O R C E   D I S T R I B U T I O N   I N   B A R   E L E M E N T S   (C B A R)

ELEMENT NO.	STATION (PCT)	BEND-MOMENT PLANE 1	BEND-MOMENT PLANE 2	SHEAR FORCE PLANE 1	SHEAR FORCE PLANE 2	AXIAL FORCE	TORQUE
1	0.000	4.635505E-02	1.904316E-01	1.601256E-03	-7.821625E-01	-3.275587E-01	-2.444526E-01
1	1.000	-4.771324E-02	4.482644E+01	1.601256E-03	-7.821625E-01	-3.275587E-01	-2.444526E-01
2	0.000	3.862334E-02	4.485786E+01	1.630658E-03	9.062846E-01	-9.752230E-01	-1.760779E-01
2	1.000	-5.844522E-02	-8.253471E+00	1.630658E-03	9.079610E-01	-9.752230E-01	-1.760779E-01
3	0.000	2.743372E-02	-5.051497E+00	8.831832E-04	-1.472171E+00	7.760780E-02	-1.625129E-01
3	1.000	-2.844253E-02	7.832680E+01	8.831832E-04	-1.472171E+00	7.760780E-02	-1.625129E-01
4	0.000	-1.135330E-02	7.412041E+01	-2.937276E-04	1.324236E+00	-3.894413E-02	1.158450E-01
4	1.000	6.347140E-03	2.389953E-01	-2.937276E-04	1.330274E+00	-3.894413E-02	1.158450E-01
5	0.000	5.608550E-02	6.547135E-14	2.291563E-03	-5.231445E-01	8.801766E-03	-3.479567E-02
5	1.000	-5.871908E-02	3.017591E+01	2.291563E-03	-3.271530E-01	8.801766E-03	-3.479567E-02
6	0.000	5.444130E-02	3.013677E+01	2.103024E-03	-2.701511E-01	-5.902761E-02	-1.391810E-02
6	1.000	-7.186594E-03	2.091974E+01	2.103024E-03	8.996577E-01	-5.902761E-02	-1.391810E-02
7	0.000	-7.184594E-03	2.091974E+01	1.917382E-03	8.996577E-01	-6.594973E-02	-1.391810E-02
7	1.000	-5.447750E-02	-2.253160E+01	1.917382E-03	2.803607E+00	-6.594973E-02	-1.391810E-02
8	0.000	2.604547E-02	-2.248460E+01	1.194035E-03	-2.376559E+00	-2.867123E-02	-1.706812E-02
8	1.000	-6.466024E-03	2.998703E+01	1.194035E-03	-1.206405E+00	-2.867123E-02	-1.706812E-02
9	0.000	-5.414492E-03	2.980703E+01	5.812650E-04	-1.206405E+00	-1.844493E-02	-1.706812E-02
9	1.000	-2.345136E-02	4.817652E+01	5.812650E-04	-1.621591E-02	-1.844493E-02	-1.706812E-02
10	0.000	-1.797334E-02	4.817752E+01	-5.841561E-04	-3.465716E-01	-6.250162E-03	2.133797E-02
10	1.000	1.648611E-02	0.0	-5.841561E-04	1.480514E+00	-6.250162E-03	2.133797E-02
11	0.000	5.835803E-02	-1.357157E-01	1.570747E-03	-1.715342E-02	8.235731E-02	-2.121050E-02
11	1.000	-5.752433E-02	1.270364E-12	1.570747E-03	3.562[illegible]E-01	8.235731E-02	-2.121050E-02
12	0.000	4.053371E-02	6.017157E-02	2.140[illegible]E-03	-1.0[illegible]E+00	1.[illegible]E-01	-8.264178E-03
12	1.000	-1.637471E-02	[illegible]	2.14[illegible]E-03	5.1[illegible]E-01	[illegible]	-8.264178E-03
13	0.000	[illegible]	[illegible]	4.25[illegible]E-04	5.1[illegible]E-01	6.75[illegible]E-02	-8.264178E-03
13	1.000	-2.[illegible]E-02	-3.[illegible]E+01	4.25[illegible]E-04	2.[illegible]E+00	6.7[illegible]E-02	-8.264178E-03
14	0.000	1.721[illegible]E-02	-3.[illegible]E+01	9.[illegible]E-04	-3.514713E+00	3.232672E-02	-1.182721E-02
14	1.000	-1.579[illegible]E-02	4.01[illegible]E+01	9.[illegible]E-04	-1.318135E+00	3.232672E-02	-1.182721E-02
15	0.000	-1.574[illegible]E-02	4.0192[illegible]E+01	-7.750[illegible]E-04	-1.[illegible]E+00	9.5[illegible]E-03	-1.182721E-02
15	1.000	6.4[illegible]E-02	4.6[illegible]E+01	-7.7[illegible]E-04	3.[illegible]E-01	9.5[illegible]E-03	-1.182721E-02
16	0.000	-4.[illegible]E-02	4.6[illegible]E+01	-1.[illegible]E-03	-1.4[illegible]E+00	4.6[illegible]E-03	2.251[illegible]E-02
16	1.000	4.[illegible]E-02	-4.5[illegible]E-13	-1.[illegible]E-03	2.[illegible]E+00	4.6[illegible]E-03	2.251[illegible]E-02
17	0.000	3.77[illegible]E-02	4.2722[illegible]E-14	1.2[illegible]E-03	-5.3[illegible]E-01	1.477703E-01	-4.443075E-03
17	1.000	-3.74[illegible]E-02	3.[illegible]E+01	1.2[illegible]E-03	-2.291351E-01	1.477703E-01	-4.443075E-03
18	0.000	[illegible]	3.61[illegible]E+01	1.[illegible]E-03	-7.13[illegible]E-01	1.552[illegible]E-01	-1.367790E-03
18	1.000	-1.7[illegible]E-02	2.8[illegible]E+01	1.[illegible]E-03	1.2[illegible]E+00	1.552[illegible]E-01	-1.367790E-03
19	0.000	-1.7[illegible]E-02	2.8[illegible]E+01	-4.[illegible]E-04	1.2[illegible]E+00	1.5[illegible]E-01	-1.367790E-03
19	1.000	-3.3[illegible]E-03	-4.134707E+01	-4.[illegible]E-04	[illegible]	1.5[illegible]E-01	-1.367790E-03
20	0.000	-6.642[illegible]E-03	-4.132457E+01	5.64[illegible]E-04	-3.[illegible]E+00	9.724[illegible]E-02	-4.105131E-03
20	1.000	-2.[illegible]E-02	4.057162E+01	5.64[illegible]E-04	-1.[illegible]E+00	9.724[illegible]E-02	-4.105131E-03
21	0.000	-2.315059E-02	4.057162E+01	-2.[illegible]E-03	-1.[illegible]E+00	6.383941E-02	-4.105131E-03
21	1.000	5.714[illegible]E-02	5.755550E+01	-2.[illegible]E-03	5.071130E-01	6.383941E-02	-4.105131E-03
22	0.000	-6.742930E-02	5.755463E+01	-2.315[illegible]E-03	-1.206907E+00	2.676072E-02	2.236534E-02
22	1.000	5.82[illegible]E-02	0.0	-2.315[illegible]E-03	2.951023E+00	2.676072E-02	2.236534E-02
23	0.000	1.557315E-02	6.968305E-14	4.967413E-04	-5.913616E-01	1.105765E-01	8.685527E-03
23	1.000	-1.341600E-02	3.357395E+01	4.967413E-04	-1.619296E-01	1.105765E-01	8.685527E-03
24	0.000	-3.679206E-03	3.354783E+01	5.177302E-04	-1.149450E+00	1.741657E-01	6.610324E-03
24	1.000	-1.883335E-02	2.978177E+01	5.177302E-04	1.436694E+00	1.741657E-01	6.610324E-03
25	0.000	-1.883833E-02	2.978177E+01	-2.043992E-03	1.436694E+00	1.991747E-01	6.610324E-03
25	1.000	4.098342E-02	-4.682818E+01	-2.043992E-03	3.962638E+00	1.991747E-01	6.610324E-03

HEGS-20 GONDOLA ASSEMBLY
RUN 1.01, 1-POINT, LIMIT LOAD, 60-40 DIST., 690 PSF

SUBCASE 1

F O R C E   D I S T R I B U T I O N   I N   B A R   E L E M E N T S   (C B A R)

ELEMENT ID.	STATION (PCT)	BEND-MOMENT PLANE 1	BEND-MOMENT PLANE 2	SHEAR FORCE PLANE 1	SHEAR FORCE PLANE 2	AXIAL FORCE	TORQUE
26	0.000	-4.951544E-02	-4.887785E+01	-9.721444E-04	-4.447350E+00	1.926825E-01	2.513613E-03
26	1.000	-2.114133E-02	4.393752E+01	-9.721444E-04	-1.893333E+00	1.926825E-01	2.513613E-03
27	0.000	-2.114133E-02	4.393752E+01	-2.751405E-03	-1.890333E+00	1.903252E-01	2.513613E-03
27	1.000	5.941930E-02	6.185493E+01	-2.751405E-03	6.658109E-01	1.903252E-01	2.513613E-03
28	0.000	-8.555551E-02	6.186578E+01	-2.995475E-03	-1.449353E+00	8.821509E-02	2.222908E-02
28	1.000	8.659948E-02	-9.094447E-13	-2.995475E-03	3.366247E+00	8.821509E-02	2.222908E-02
29	0.000	4.057943E-03	-5.468588E-02	1.363351E-04	-1.245353E+00	1.943003E-02	9.519428E-02
29	1.000	-3.925837E-03	7.233237E+01	1.363351E-04	-1.025472E+00	1.943003E-02	9.519428E-02
30	0.000	-2.062678E-02	7.235069E+01	-2.100754E-04	9.555523E-01	-1.154231E-01	1.120068E-01
30	1.000	-1.467577E-02	2.520934E+01	-2.100754E-04	2.264768E+00	-1.154231E-01	1.120068E-01
31	0.000	-1.467577E-02	2.520934E+01	-2.111557E-03	2.264768E+00	-4.360670E-01	1.120068E-01
31	1.000	4.715161E-02	-6.026414E+01	-2.111557E-03	3.573584E+00	-4.360670E-01	1.120068E-01
32	0.000	-6.883004E-02	-5.021900E+01	-2.115230E-03	-4.963457E+00	1.366428E+00	6.206655E-02
32	1.000	-6.882952E-03	6.598678E+01	-2.115230E-03	-3.654264E+00	1.366428E+00	6.206655E-02
33	0.000	-6.882962E-03	6.598678E+01	-1.374620E-03	-3.654264E+00	1.362069E+00	6.206655E-02
33	1.000	3.136592E-02	1.538203E+02	-1.374620E-03	-2.345388E+00	1.362069E+00	6.206655E-02
34	0.000	-7.713252E-02	1.538256E+02	-2.552914E-03	1.325068E+00	5.670171E-01	1.319707E-01
34	1.000	7.233603E-02	-2.306963E-01	-2.552914E-03	3.814436E+00	5.670171E-01	1.319707E-01
35	0.000	-4.605385E-02	2.444526E-01	-3.544492E-03	-7.942532E-01	-9.153114E-02	1.904016E-01
35	1.000	2.795213E-02	1.082840E+01	-3.544492E-03	-7.942532E-01	-9.153114E-02	1.904016E-01
36	0.000	-3.611237E-02	1.686326E+01	-5.337512E-03	-2.705346E-01	-2.903476E-01	1.904016E-01
36	1.000	4.593344E-02	2.112418E+01	-5.337512E-03	-2.705346E-01	-2.903476E-01	1.904016E-01
37	0.000	-1.240339E-02	2.114539E+01	-3.411501E-03	-2.526838E-01	-4.338225E-01	5.468586E-02
37	1.000	4.112574E-02	2.512511E+01	-3.411501E-03	-2.526838E-01	-4.338225E-01	5.468586E-02
38	0.000	3.407694E-03	2.512955E+01	-1.530930E-03	3.463686E-01	-5.271922E-01	5.468586E-02
38	1.000	2.751924E-02	1.967420E+01	-1.530930E-03	3.463686E-01	-5.271922E-01	5.468586E-02
39	0.000	1.224605E-02	1.965597E+01	3.923384E-04	9.377286E-01	-5.637530E-01	5.468586E-02
39	1.000	4.057943E-03	9.519428E-02	3.923384E-04	9.377286E-01	-5.637530E-01	5.468586E-02
40	0.000	-7.958050E-02	6.435022E-03	-7.505038E-03	-1.208588E+01	-2.687147E-02	2.093747E-01
40	1.000	7.702459E-02	2.523593E+02	-7.505038E-03	-1.208588E+01	-2.687147E-02	2.093747E-01
41	0.000	-1.585810E-02	2.523524E+02	-4.313887E-03	-7.639509E+00	-1.910501E-03	2.761549E-01
41	1.000	5.208501E-02	3.720847E+02	-4.313887E-03	-7.639509E+00	-1.910501E-03	2.761549E-01
42	0.000	1.251746E-02	3.720883E+02	-4.570227E-04	-1.400035E+00	6.267302E-03	-1.797237E-02
42	1.000	1.471607E-02	3.947388E+02	-4.570227E-04	-1.400035E+00	6.267302E-03	-1.797237E-02
43	0.000	2.299956E-02	3.947410E+02	-7.143397E-04	5.987847E+00	-5.239531E-04	4.524663E-03
43	1.000	3.425051E-02	3.004330E+02	-7.143397E-04	5.987847E+00	-5.239531E-04	4.524663E-03
44	0.000	1.248493E-01	3.004371E+02	1.153991E-02	1.439804E+01	-1.658479E-02	-4.514492E-02
44	1.000	[illegible]	-4.493827E-02	1.153991E-02	1.439804E+01	-1.658479E-02	-4.514492E-02
45	0.000	[illegible]	[illegible]	2.633746E-05	-5.091159E+00	-1.412446E-02	-2.306963E-01
45	1.000	[illegible]	1.064202E+02	2.633746E-05	-5.091159E+00	-1.412446E-02	-2.306963E-01
46	0.000	[illegible]	1.064418E+02	9.262708E-04	-3.210280E+00	-9.071849E-02	-2.306963E-01
46	1.000	[illegible]	1.570835E+02	9.262708E-04	-3.210280E+00	-9.071849E-02	-2.306963E-01
47	0.000	6.603126E-02	1.571269E+02	3.967437E-03	-4.250106E-01	-2.418450E-01	-2.306963E-01
47	1.000	-1.448587E-02	1.637199E+02	3.967437E-03	-4.250106E-01	-2.418450E-01	-2.306963E-01
48	0.000	5.312430E-02	1.637423E+02	5.808804E-03	2.556013E+00	-4.587781E-01	-2.306963E-01
48	1.000	-3.776436E-02	1.234851E+02	5.808804E-03	2.556013E+00	-4.587781E-01	-2.306963E-01
49	0.000	4.909512E-02	1.235073E+02	5.819842E-03	5.924260E+00	-7.784097E-01	-2.306963E-01
49	1.000	-7.236593E-02	-1.319707E-01	5.819842E-03	5.924260E+00	-7.784097E-01	-2.306963E-01
50	0.000	-6.837167E-02	-6.837470E-02	-7.339488E-03	-1.668367E+00	-1.849060E-02	3.524605E-02
50	1.000	6.687604E-02	3.476712E+01	-7.339488E-03	-1.668367E+00	-1.849060E-02	3.524605E-02

HEGS-20 GONDOLA ASSEMBLY
RUN 1.01, 1-POINT, LIMIT LOAD, 60-40 DIST., 690 PSF

SUBCASE 1

F O R C E   D I S T R I B U T I O N   I N   B A R   E L E M E N T S   (C B A R)

ELEMENT ID.	STATION (PCT)	BEND-MOMENT PLANE 1	BEND-MOMENT PLANE 2	SHEAR FORCE PLANE 1	SHEAR FORCE PLANE 2	AXIAL FORCE	TORQUE
51	0.000	-5.578059E-02	3.474625E+01	-8.286185E-03	-1.725149E+00	-2.875195E-02	-1.775901E-02
51	1.000	7.472652E-02	6.191735E+01	-8.286185E-03	-1.725149E+00	-2.875195E-02	-1.775901E-02
52	0.000	-2.433159E-02	6.190440E+01	-5.483744E-03	3.098595E-01	-3.260172E-02	5.042267E-02
52	1.000	5.703746E-02	5.702412E+01	-5.483744E-03	3.098595E-01	-3.260172E-02	5.042267E-02
53	0.000	-5.167795E-03	5.702104E+01	-2.843900E-03	9.939038E-01	-2.476504E-02	-2.195701E-03
53	1.000	3.962363E-02	4.136705E+01	-2.843900E-03	9.939038E-01	-2.476504E-02	-2.195701E-03
54	0.000	2.944663E-02	4.136913E+01	2.222701E-03	1.981424E+00	8.348195E-03	-2.831454E-02
54	1.000	-1.690094E-02	1.681253E-02	2.222701E-03	1.981424E+00	8.348195E-03	-2.831454E-02
55	0.000	-1.782765E-02	-2.993587E-01	-1.858473E-03	-2.799630E+00	2.423464E-02	-2.189229E-03
55	1.000	2.047706E-02	5.815691E+01	-1.858473E-03	-2.799630E+00	2.423464E-02	-2.189229E-03
56	0.000	1.549624E-02	5.811851E+01	3.564204E-04	-2.491325E+00	5.688672E-02	-1.196709E-03
56	1.000	9.862657E-03	9.735688E+01	3.564204E-04	-2.491325E+00	5.688672E-02	-1.196709E-03
57	0.000	5.743927E-02	9.732254E+01	5.416355E-03	-2.029140E-01	6.393503E-02	-3.135930E-03
57	1.000	-2.786632E-02	1.005164E+02	5.416355E-03	-2.029140E-01	6.393503E-02	-3.135930E-03
58	0.000	7.730104E-02	1.004920E+02	8.217965E-03	1.511107E+00	6.062525E-02	-7.007452E-03
58	1.000	-5.213190E-02	7.669203E+01	8.217965E-03	1.511107E+00	6.062525E-02	-7.007452E-03
59	0.000	9.584341E-02	7.667232E+01	9.887013E-03	3.670456E+00	3.533650E-02	-4.761166E-03
59	1.000	-1.104955E-01	6.990217E-02	9.887013E-03	3.670456E+00	3.533650E-02	-4.761166E-03
64	0.000	2.192903E-02	1.403217E-01	1.035735E-04	3.952212E-03	-2.918483E+00	1.395985E-01
64	1.000	1.271096E-02	-2.114252E-01	1.035735E-04	3.952212E-03	-2.918483E+00	1.395985E-01
65	0.000	-1.931272E-02	-1.114629E-01	-1.534934E-04	-2.563237E-03	-4.009578E+00	6.649444E-02
65	1.000	-5.651814E-03	1.166651E-01	-1.534934E-04	-2.563237E-03	-4.009578E+00	6.649444E-02
80	0.000	-6.722394E-02	-5.373794E-03	-1.578917E-03	-3.734510E-04	-1.666053E-01	1.237950E-01
80	1.000	7.324966E-02	2.786335E-02	-1.578917E-03	-3.734510E-04	-1.666053E-01	1.237950E-01
85	0.000	8.074796E-02	1.395985E-01	3.826264E-04	6.042015E-04	-1.550039E+01	-1.168307E-01
85	1.000	3.593476E-02	6.883444E-02	3.826264E-04	6.042015E-04	-1.550039E+01	-1.168307E-01
86	0.000	7.996275E-02	-1.925290E-01	4.927247E-04	-2.659226E-03	-2.324642E+01	-1.445285E-01
86	1.000	2.225484E-02	1.189196E-01	4.927247E-04	-2.659226E-03	-2.324642E+01	-1.445285E-01
87	0.000	3.534967E-02	-2.435142E-02	1.463865E-05	-6.999864E-04	-2.304655E+01	-1.166651E-01
87	1.000	3.363505E-02	5.763798E-02	1.463865E-05	-6.999864E-04	-2.304655E+01	-1.166651E-01
88	0.000	1.031587E-01	1.926295E-01	1.045603E-03	2.212276E-03	-1.566904E+01	-1.114629E-01
88	1.000	-1.931272E-02	-6.649444E-02	1.045603E-03	2.212276E-03	-1.566904E+01	-1.114629E-01

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F

HEOS-20 GONDOLA ASSEMBLY
RUN 1.01, 1-POINT, LIMIT LOAD, 60-40 DIST., 690 PSF

SUBCASE 1

FORCES IN ROD ELEMENTS (CONROD)

ELEMENT ID.	AXIAL FORCE	TORQUE	ELEMENT ID.	AXIAL FORCE	TORQUE
60	1.555581E+00	0.0	61	1.467448E+00	0.0
62	8.552755E+00	0.0	63	6.421892E+00	0.0
66	-1.044[illegible]E-04	0.0	67	9.802204E-01	0.0
68	2.314207E-05	0.0	69	1.624769E+00	0.0
70	-1.420402E-04	0.0	71	1.260939E+01	0.0
72	1.039286E+01	0.0	73	2.079724E-04	0.0
74	1.633420E+01	0.0	75	3.341408E-04	0.0
76	-2.403525E-04	0.0	77	2.007125E+01	0.0
78	1.193095E-03	0.0	79	1.876990E-03	0.0
81	2.614301E-01	0.0	82	3.239758E-02	0.0
83	2.418845E-01	0.0	84	1.183217E-02	0.0
89	1.175398E+01	0.0	90	1.633639E+01	0.0
91	2.175329E+01	0.0	92	1.630077E+01	0.0

FORCES IN QUADRILATERAL ELEMENTS (QUAD4)

ELEMENT ID	- MEMBRANE FORCES - FX	FY	FXY	- BENDING MOMENTS - MX	MY	MXY	- TRANSVERSE SHEAR FORCES - QX	QY
93	-1.574837E-03	-1.053481E-03	1.145103E-02	0.0	0.0	0.0	0.0	0.0
94	1.857779E-04	-1.471724E-03	1.197[illegible]2E-02	0.0	0.0	0.0	0.0	0.0
95	7.115668E-04	-1.493073E-03	8.812255E-03	0.0	0.0	0.0	0.0	0.0
96	8.044971E-04	-2.330759E-03	4.7[illegible]52E-03	0.0	0.0	0.0	0.0	0.0
97	1.071418E-04	-2.461950E-03	6.2[illegible]E-04	0.0	0.0	0.0	0.0	0.0
98	-1.951035E-04	5.583417E-05	-1.412401E-03	0.0	0.0	0.0	0.0	0.0
99	-9.941282E-06	4.524[illegible]E-06	-4.573452E-03	0.0	0.0	0.0	0.0	0.0
100	4.625312E-05	-6.117956E-04	-9.855794E-03	0.0	0.0	0.0	0.0	0.0
101	3.468608E-04	-1.523375E-03	-1.425345E-02	0.0	0.0	0.0	0.0	0.0
102	2.240997E-03	-2.581104E-03	-1.694079E-02	0.0	0.0	0.0	0.0	0.0
103	5.344785E-04	7.487951E-04	1.055577E-02	0.0	0.0	0.0	0.0	0.0
104	1.888591E-03	1.195452E-04	6.445176E-03	0.0	0.0	0.0	0.0	0.0
105	2.236525E-03	-3.554871E-04	1.343514E-03	0.0	0.0	0.0	0.0	0.0
106	7.[illegible]5548E-04	-1.459359E-04	-5.295603E-03	0.0	0.0	0.0	0.0	0.0
107	2.676013E-04	6.753776E-04	8.729064E-03	0.0	0.0	0.0	0.0	0.0
108	1.497392E-03	2.553[illegible]E-04	3.475929E-03	0.0	0.0	0.0	0.0	0.0
109	2.277964E-03	-1.615590E-04	-1.587157E-03	0.0	0.0	0.0	0.0	0.0
110	-3.924827E-04	-5.775149E-04	-1.048903E-02	0.0	0.0	0.0	0.0	0.0
111	8.447312E-04	2.722659E-03	3.898417E-03	0.0	0.0	0.0	0.0	0.0
112	1.567432E-03	2.253317E-03	-6.509333E-04	0.0	0.0	0.0	0.0	0.0
113	2.648123E-03	2.171359E-03	-5.165545E-03	0.0	0.0	0.0	0.0	0.0
114	8.672911E-03	1.742088E-03	-1.367649E-02	0.0	0.0	0.0	0.0	0.0
115	8.863249E-04	3.157843E-03	1.802726E-03	0.0	0.0	0.0	0.0	0.0
116	1.293407E-03	2.625790E-03	-4.165107E-03	0.0	0.0	0.0	0.0	0.0
117	2.524973E-03	2.531762E-03	-9.303603E-03	0.0	0.0	0.0	0.0	0.0
118	6.809358E-03	1.527405E-03	-1.392633E-02	0.0	0.0	0.0	0.0	0.0

FORCES IN TRIANGULAR ELEMENTS (TRIA3)

ELEMENT ID	- MEMBRANE FORCES - FX	FY	FXY	- BENDING MOMENTS - MX	MY	MXY	- TRANSVERSE SHEAR FORCES - QX	QY
119	-9.683736E-04	-5.627329E-04	1.056964E-02	0.0	0.0	0.0	0.0	0.0
120	-6.159231E-03	3.267522E-03	1.250239E-02	0.0	0.0	0.0	0.0	0.0
121	-1.049986E-03	-4.260349E-04	1.442222E-02	0.0	0.0	0.0	0.0	0.0
122	-4.645303E-04	-2.503982E-04	7.952234E-03	0.0	0.0	0.0	0.0	0.0
123	1.621520E-03	3.518205E-03	6.575033E-03	0.0	0.0	0.0	0.0	0.0
124	-1.615012E-04	3.083170E-04	5.399028E-03	0.0	0.0	0.0	0.0	0.0

MEGS-20 GONDOLA ASSEMBLY
RUN 1.01, 1-POINT, LIMIT LOAD, 60-40 DIST., 690 PSF

SUBCASE 1

S T R E S S   D I S T R I B U T I O N   I N   B A R   E L E M E N T S   (C B A R)

ELEMENT ID.	STATION (PCT)	SXC	SXD	SXE	SXF	AXIAL	S-MAX	S-MIN	M.S.
1	0.000	-2.417166E-02	2.384764E-02	0.0	0.0	-7.100102E-02	-4.715338E-02	-9.517268E-02	3.7E+00
1	1.000	-5.690276E+00	5.613999E+00	0.0	0.0	-7.100102E-02	5.542998E+00	-5.761277E+00	3.7E+00
2	0.000	-4.768372E+00	4.543957E+00	0.0	0.0	-1.784672E-01	4.365470E+00	-4.946659E+00	4.5E+00
2	1.000	8.781267E-01	-8.367492E-01	0.0	0.0	-1.784672E-01	6.996349E-01	-1.015286E+00	2.6E+01
3	0.000	8.558703E-01	-8.155903E-01	0.0	0.0	1.415166E-02	8.700220E-01	-8.014366E-01	2.9E+01
3	1.000	-8.304395E+00	7.913563E+00	0.0	0.0	1.415166E-02	7.927715E+00	-8.290244E+00	2.3E+00
4	0.000	-9.917459E+00	9.704518E+00	0.0	0.0	-8.440427E-03	9.776077E+00	-9.925900E+00	1.7E+00
4	1.000	-2.928711E-02	2.689452E-02	0.0	0.0	-8.440427E-03	2.045410E-02	-3.772754E-02	7.1E+02
5	0.000	-1.200900E-14	1.576093E-14	0.0	0.0	3.061355E-03	3.061355E-03	3.061355E-03	8.5E+03
5	1.000	-5.447928E+00	7.114460E+00	0.0	0.0	3.061355E-03	7.117521E+00	-5.444867E+00	2.7E+00
6	0.000	-5.438362E+00	7.101467E+00	0.0	0.0	-1.995584E-02	7.081978E+00	-5.458350E+00	2.7E+00
6	1.000	-3.775249E+00	4.930601E+00	0.0	0.0	-1.995584E-02	4.910127E+00	-3.795017E+00	4.3E+00
7	0.000	-3.775249E+00	4.930631E+00	0.0	0.0	-2.305430E-02	4.907540E+00	-3.798603E+00	4.3E+00
7	1.000	4.070123E+00	-5.315181E+00	0.0	0.0	-2.305430E-02	4.047066E+00	-5.338235E+00	4.1E+00
8	0.000	4.056970E+00	-5.299441E+00	0.0	0.0	-9.735271E-03	4.048335E+00	-5.309176E+00	4.1E+00
8	1.000	-5.412106E+00	7.067666E+00	0.0	0.0	-9.735271E-03	7.057945E+00	-5.421842E+00	2.7E+00
9	0.000	-5.412106E+00	7.067683E+00	0.0	0.0	-6.351407E-03	7.061329E+00	-5.418456E+00	2.7E+00
9	1.000	-8.694975E+00	1.135479E+01	0.0	0.0	-6.351407E-03	1.134843E+01	-8.701327E+00	1.3E+00
10	0.000	-8.695155E+00	1.135502E+01	0.0	0.0	-2.152260E-03	1.135287E+01	-8.697307E+00	1.3E+00
10	1.000	0.0	0.0	0.0	0.0	-2.152260E-03	-2.152260E-03	-2.152260E-03	1.3E+04
11	0.000	2.449419E-02	-3.198701E-02	0.0	0.0	2.830340E-02	5.265756E-02	-3.623600E-03	4.9E+02
11	1.000	-2.298700E-13	3.001676E-13	0.0	0.0	2.830340E-02	2.830340E-02	2.830340E-02	9.2E+02
12	0.000	-1.230554E-02	1.606982E-02	0.0	0.0	3.570574E-02	5.177556E-02	2.340020E-02	5.0E+02
12	1.000	-3.088007E+00	4.032634E+00	0.0	0.0	3.570574E-02	4.068339E+00	-3.052301E+00	5.4E+00
13	0.000	-3.088007E+00	4.032634E+00	0.0	0.0	2.330628E-02	4.055942E+00	-3.064698E+00	5.4E+00
13	1.000	5.472092E+00	-7.145896E+00	0.0	0.0	2.330628E-02	5.495310E+00	-7.122590E+00	2.6E+00
14	0.000	5.525087E+00	-7.215221E+00	0.0	0.0	1.113179E-02	5.536218E+00	-7.204089E+00	2.7E+00
14	1.000	-7.254075E+00	9.473110E+00	0.0	0.0	1.113179E-02	9.484242E+00	-7.242943E+00	1.7E+00
15	0.000	-7.254075E+00	9.473110E+00	0.0	0.0	3.300250E-03	9.476411E+00	-7.250775E+00	1.7E+00
15	1.000	-8.391177E+00	1.095805E+01	0.0	0.0	3.300250E-03	1.096135E+01	-8.387877E+00	1.4E+00
16	0.000	-8.390827E+00	1.095766E+01	0.0	0.0	1.587262E-03	1.095918E+01	-8.389240E+00	1.4E+00
16	1.000	8.207352E-14	-1.071800E-13	0.0	0.0	1.587262E-03	1.587262E-03	1.587262E-03	1.6E+04
17	0.000	-1.691523E-14	2.208953E-14	0.0	0.0	3.711100E-02	3.711100E-02	3.711100E-02	7.0E+02
17	1.000	-6.167131E+00	8.053666E+00	0.0	0.0	3.711100E-02	8.090779E+00	-6.130020E+00	2.2E+00
18	0.000	-6.157635E+00	8.041267E+00	0.0	0.0	5.690562E-02	8.098172E+00	-6.100729E+00	2.2E+00
18	1.000	-5.165406E+00	6.745610E+00	0.0	0.0	5.690562E-02	6.802516E+00	-5.108574E+00	2.6E+00
19	0.000	-5.165406E+00	6.745610E+00	0.0	0.0	4.773229E-02	6.793343E+00	-5.117745E+00	2.6E+00
19	1.000	7.462384E+00	-9.745142E+00	0.0	0.0	4.773229E-02	7.510116E+00	-9.697409E+00	1.6E+00
20	0.000	7.458324E+00	-9.739639E+00	0.0	0.0	3.346508E-02	7.491609E+00	-9.706354E+00	1.6E+00
20	1.000	-7.322431E+00	9.562376E+00	0.0	0.0	3.346508E-02	9.595861E+00	-7.288946E+00	1.7E+00
21	0.000	-7.322431E+00	9.562376E+00	0.0	0.0	2.198327E-02	9.584360E+00	-7.300447E+00	1.7E+00
21	1.000	-1.045344E+01	1.366031E+01	0.0	0.0	2.198327E-02	1.368229E+01	-1.043046E+01	9.0E-01
22	0.000	-1.045974E+01	1.365940E+01	0.0	0.0	9.903629E-03	1.366930E+01	-1.044984E+01	9.0E-01
22	1.000	0.0	0.0	0.0	0.0	9.903629E-03	9.903629E-03	9.903629E-03	2.6E+03
23	0.000	-1.257651E-14	1.642368E-14	0.0	0.0	3.807523E-02	3.807523E-02	3.807523E-02	6.8E+02
23	1.000	-6.059408E+00	7.913068E+00	0.0	0.0	3.807523E-02	7.951162E+00	-6.021405E+00	2.3E+00
24	0.000	-6.054758E+00	7.906930E+00	0.0	0.0	5.997545E-02	7.966900E+00	-5.994790E+00	2.3E+00
24	1.000	-5.375062E+00	7.019303E+00	0.0	0.0	5.997545E-02	7.079279E+00	-5.315086E+00	2.7E+00
25	0.000	-5.375062E+00	7.019303E+00	0.0	0.0	6.858032E-02	7.087890E+00	-5.306475E+00	2.7E+00
25	1.000	8.812568E+00	-1.150637E+01	0.0	0.0	6.858032E-02	8.881174E+00	-1.143979E+01	1.4E+00

MEGS-20 GONDOLA ASSEMBLY
RUN 1.01, 1-POINT, LIMIT LOAD, 60-40 DIST., 690 PSF

SUBCASE 1

S T R E S S   D I S T R I B U T I O N . I N   B A R   E L E M E N T S   (C B A R)

ELEMENT ID.	STATION (PCT)	SXC	SXD	SXE	SXF	AXIAL	S-MAX	S-MIN	M.S.
26	0.000	8.821552E+00	-1.152008E+01	0.0	0.0	6.635072E-02	8.887903E+00	-1.145373E+01	1.4E+00
26	1.000	-7.929914E+00	1.035569E+01	0.0	0.0	6.635072E-02	1.042204E+01	-7.863563E+00	1.5E+00
27	0.000	-7.929914E+00	1.035569E+01	0.0	0.0	6.553898E-02	1.042123E+01	-7.864375E+00	1.5E+00
27	1.000	-1.116541E+01	1.458093E+01	0.0	0.0	6.553898E-02	1.464647E+01	-1.109987E+01	7.8E-01
28	0.000	-1.116581E+01	1.458146E+01	0.0	0.0	3.037710E-02	1.461184E+01	-1.113544E+01	7.8E-01
28	1.000	1.641470E-13	-2.143599E-13	0.0	0.0	3.037710E-02	3.037710E-02	3.037710E-02	8.5E+02
29	0.000	6.942422E-03	-6.849360E-03	0.0	0.0	4.211103E-03	1.115352E-02	-2.638257E-03	2.3E+03
29	1.000	-9.182563E+00	9.059571E+00	0.0	0.0	4.211103E-03	9.063782E+00	-9.178451E+00	1.9E+00
30	0.000	-7.691907E+00	7.329901E+00	0.0	0.0	-2.104724E-02	7.308853E+00	-7.712954E+00	2.5E+00
30	1.000	-2.679741E+00	2.553623E+00	0.0	0.0	-2.104724E-02	2.532576E+00	-2.700788E+00	9.0E+00
31	0.000	-2.679741E+00	2.553623E+00	0.0	0.0	-7.951623E-02	2.474107E+00	-2.759257E+00	8.8E+00
31	1.000	6.406050E+00	-6.104561E+00	0.0	0.0	-7.951623E-02	6.326534E+00	-6.184077E+00	3.1E+00
32	0.000	6.401251E+00	-6.099988E+00	0.0	0.0	3.404135E-01	6.741665E+00	-5.759574E+00	2.9E+00
32	1.000	-7.014363E+00	6.684245E+00	0.0	0.0	3.404135E-01	7.024658E+00	-6.673950E+00	2.7E+00
33	0.000	-7.014363E+00	6.684245E+00	0.0	0.0	2.520184E-01	6.936263E+00	-6.762345E+00	2.7E+00
33	1.000	-1.635108E+01	1.558154E+01	0.0	0.0	2.520184E-01	1.583356E+01	-1.609906E+01	6.4E-01
34	0.000	-1.952830E+01	1.926653E+01	0.0	0.0	1.225906E-01	1.938942E+01	-1.940541E+01	3.4E-01
34	.000	2.928711E-02	-2.889452E-02	0.0	0.0	1.225906E-01	1.521777E-01	9.399605E-02	1.7E+02
35	0.000	-3.120951E-02	3.303833E-02	0.0	0.0	-2.074595E-02	1.229238E-02	-5.195546E-02	1.1E+01
35	1.000	-2.148507E+00	2.274405E+00	0.0	0.0	-2.074595E-02	2.253659E+00	-2.169253E+00	1.1E+01
36	0.000	-2.152944E+00	2.279108E+00	0.0	0.0	-6.580862E-02	2.213299E+00	-2.218758E+00	8.3E+00
36	1.000	-2.696945E+00	2.854981E+00	0.0	0.0	-6.580862E-02	2.789173E+00	-2.762754E+00	8.8E+00
37	0.000	-2.699653E+00	2.857848E+00	0.0	0.0	-9.832786E-02	2.759520E+00	-2.797981E+00	6.9E+00
37	1.000	-3.207748E+00	3.395717E+00	0.0	0.0	-9.832786E-02	3.297389E+00	-3.306076E+00	7.2E+00
38	0.000	-3.208315E+00	3.396317E+00	0.0	0.0	-1.194905E-01	3.276827E+00	-3.327806E+00	6.9E+00
38	1.000	-2.511835E+00	2.659024E+00	0.0	0.0	-1.194905E-01	2.539533E+00	-2.631325E+00	7.1E+00
39	0.000	-2.510725E+00	2.657850E+00	0.0	0.0	-1.277772E-01	2.530073E+00	-2.638503E+00	9.3E+00
39	1.000	-1.215355E-02	1.286573E-02	0.0	0.0	-1.277772E-01	-1.149115E-01	-1.399308E-01	9.2E+00
40	0.000	-2.735890E-04	3.191351E-04	0.0	0.0	-2.775978E-03	-2.456843E-03	-3.049567E-03	1.1E+00
40	1.000	-1.072921E+01	1.251537E+01	0.0	0.0	-2.775978E-03	1.251260E+01	-1.073199E+01	1.5E+00
41	0.000	-1.072935E+01	1.251553E+01	0.0	0.0	-1.973968E-04	1.251533E+01	-1.072955E+01	4.1E-01
41	1.000	-1.584492E+01	1.848273E+01	0.0	0.0	-1.973968E-04	1.848253E+01	-1.584512E+01	7.0E-01
42	0.000	-1.584508E+01	1.848290E+01	0.0	0.0	6.474480E-04	1.848355E+01	-1.584443E+01	3.3E-01
42	1.000	-1.678257E+01	1.957647E+01	0.0	0.0	6.474480E-04	1.957711E+01	-1.678192E+01	6.1E-01
43	0.000	-1.678269E+01	1.957660E+01	0.0	0.0	-5.412739E-05	1.957655E+01	-1.678274E+01	3.3E-01
43	1.000	-1.277310E+01	1.489951E+01	0.0	0.0	-5.412739E-05	1.489946E+01	-1.277315E+01	6.1E-01
44	0.000	-1.277327E+01	1.489972E+01	0.0	0.0	-1.713305E-03	1.489800E+01	-1.277498E+01	7.5E-01
44	1.000	2.123157E-03	-2.476612E-03	0.0	0.0	-1.713305E-03	4.098519E-04	-4.189917E-03	1.1E+00
45	0.000	-1.491783E-02	1.579199E-02	0.0	0.0	-3.201373E-03	1.259061E-02	-1.811920E-02	8.1E-01
45	1.000	-1.358678E+01	1.438294E+01	0.0	0.0	-3.201373E-03	1.437974E+01	-1.358998E+01	9.9E-01
46	0.000	-1.358951E+01	1.438583E+01	0.0	0.0	-2.056176E-02	1.436527E+01	-1.361007E+01	2.3E-01
46	1.000	-2.004480E+01	2.121939E+01	0.0	0.0	-2.056176E-02	2.119883E+01	-2.006536E+01	3.5E-01
47	0.000	-2.004767E+01	2.122243E+01	0.0	0.0	-5.481551E-02	2.116761E+01	-2.010249E+01	1.8E-01
47	1.000	-2.090229E+01	2.212713E+01	0.0	0.0	-5.481551E-02	2.207231E+01	-2.095711E+01	2.9E-01
48	0.000	-2.090515E+01	2.213015E+01	0.0	0.0	-1.039841E-01	2.202617E+01	-2.100913E+01	1.8E-01
48	1.000	-1.576547E+01	1.668930E+01	0.0	0.0	-1.039841E-01	1.658531E+01	-1.586945E+01	2.9E-01
49	0.000	-1.576831E+01	1.669230E+01	0.0	0.0	-1.764301E-01	1.651587E+01	-1.594474E+01	5.7E-01
49	1.000	1.684884E-02	-1.783615E-02	0.0	0.0	-1.764301E-01	-1.595813E-01	-1.942663E-01	6.9E-01
50	0.000	1.186475E-02	-1.637118E-02	0.0	0.0	-6.805519E-03	5.059230E-03	-2.317670E-02	2.1E+00
50	1.000	-6.032980E+00	8.324405E+00	0.0	0.0	-6.805519E-03	8.317600E+00	-6.039785E+00	3.5E+00

MEGS-70 GONDOLA ASSEMBLY
RUN 1.01, 1-POINT, LIMIT LOAD, 60-40 DIST., 690 PSF

SUBCASE 1

S T R E S S   D I S T R I B U T I O N   I N   B A R   E L E M E N T S   (C B A R)

ELEMENT ID.	STATION (PCT)	SXC	SXD	SXE	SXF	AXIAL	S-MAX	S-MIN	M.S.
51	0.000	-6.029357E+00	8.319407E+00	0.0	0.0	-1.058224E-02	8.308824E+00	-6.039939E+00	7.6E-01
51	1.000	-1.074423E+01	1.482507E+01	0.0	0.0	-1.058224E-02	1.481449E+01	-1.075482E+01	1.5E+00
52	0.000	-1.074199E+01	1.482197E+01	0.0	0.0	-1.199916E-02	1.480997E+01	-1.075399E+01	7.6E-01
52	1.000	-9.845134E+00	1.365347E+01	0.0	0.0	-1.199916E-02	1.364147E+01	-9.857133E+00	1.5E+00
53	0.000	-9.894601E+00	1.365273E+01	0.0	0.0	-9.114846E-03	1.364362E+01	-9.903715E+00	9.1E-01
53	1.000	-7.178235E+00	9.904649E+00	0.0	0.0	-9.114848E-03	9.895534E+00	-7.187351E+00	1.7E+00
54	0.000	-7.178596E+00	9.905146E+00	0.0	0.0	3.072578E-03	9.908218E+00	-7.175524E+00	1.6E+00
54	1.000	-2.917401E-03	4.025479E-03	0.0	0.0	3.072578E-03	7.098057E-03	1.551770E-04	2.8E+00
55	0.000	5.194635E-02	-7.167644E-02	0.0	0.0	8.919634E-03	6.086597E-02	-6.275680E-02	8.7E-01
55	1.000	-1.009170E+01	1.392470E+01	0.0	0.0	8.919634E-03	1.393362E+01	-1.008278E+01	1.7E+00
56	0.000	-1.008504E+01	1.391550E+01	0.0	0.0	2.093733E-02	1.393644E+01	-1.006410E+01	1.1E-01
56	1.000	-1.689193E+01	2.331048E+01	0.0	0.0	2.093733E-02	2.333141E+01	-1.687296E+01	9.0E-01
57	0.000	-1.688794E+01	2.330225E+01	0.0	0.0	2.353148E-02	2.332578E+01	-1.686440E+01	7.9E-02
57	1.000	-1.744251E+01	2.405746E+01	0.0	0.0	2.353148E-02	2.408099E+01	-1.741897E+01	5.5E-01
58	0.000	-1.743791E+01	2.400112E+01	0.0	0.0	2.231330E-02	2.402343E+01	-1.741560E+01	8.0E-02
58	1.000	-1.330802E+01	1.836262E+01	0.0	0.0	2.231330E-02	1.838494E+01	-1.328571E+01	5.5E-01
59	0.000	-1.330450E+01	1.835791E+01	0.0	0.0	1.300570E-02	1.837091E+01	-1.329149E+01	4.2E-01
59	1.000	-1.212480E-02	1.673690E-02	0.0	0.0	1.300570E-02	2.974261E-02	8.759000E-04	1.0E+00
64	0.000	-5.608834E-02	5.608834E-02	0.0	0.0	-1.552650E+00	-1.496562E+00	-1.608739E+00	
64	1.000	8.450932E-02	-8.450932E-02	0.0	0.0	-1.552650E+00	-1.468141E+00	-1.637160E+00	6.8E+00
65	0.000	4.455314E-02	-4.455314E-02	0.0	0.0	-2.132754E+00	-2.088201E+00	-2.177307E+00	
65	1.000	-4.663253E-02	4.663253E-02	0.0	0.0	-2.132754E+00	-2.086122E+00	-2.179387E+00	6.3E+00
80	0.000	2.147973E-03	-2.147973E-03	0.0	0.0	-8.861985E-02	-8.647188E-02	-9.076782E-02	
80	1.000	-1.113733E-02	1.113733E-02	0.0	0.0	-8.861985E-02	-7.748252E-02	-9.975718E-02	1.6E+02
85	0.000	-5.579929E-02	5.579929E-02	0.0	0.0	-8.244890E+00	-8.189091E+00	-8.300690E+00	
85	1.000	-2.751400E-02	2.751400E-02	0.0	0.0	-8.244890E+00	-8.217376E+00	-8.272404E+00	9.3E-01
86	0.000	7.695626E-02	-7.695626E-02	0.0	0.0	-1.230511E+01	-1.226816E+01	-1.244207E+01	
86	1.000	-4.753365E-02	4.753365E-02	0.0	0.0	-1.230511E+01	-1.231758E+01	-1.241265E+01	2.9E-01
87	0.000	9.733572E-03	-9.733572E-03	0.0	0.0	-1.225880E+01	-1.224907E+01	-1.226854E+01	
87	1.000	-2.303863E-02	2.303863E-02	0.0	0.0	-1.225880E+01	-1.223577E+01	-1.228184E+01	3.0E-01
88	0.000	-7.699643E-02	7.699643E-02	0.0	0.0	-8.334598E+00	-8.257601E+00	-8.411594E+00	
88	1.000	2.657867E-02	-2.657867E-02	0.0	0.0	-8.334598E+00	-8.308019E+00	-8.361177E+00	9.0E-01

S T R E S S E S   I N   R O D   E L E M E N T S   (C O N R O D)

ELEMENT ID.	AXIAL STRESS	SAFETY MARGIN	TORSIONAL STRESS	SAFETY MARGIN	ELEMENT ID.	AXIAL STRESS	SAFETY MARGIN	TORSIONAL STRESS	SAFETY MARGIN
60	1.093105E+00	1.4E+01	0.0		61	1.030512E+00	1.5E+01	0.0	
62	6.006147E+00	1.7E+00	0.0		63	4.509754E+00	2.5E+00	0.0	
66	-2.049157E-04	4.8E+04	0.0		67	1.961653E+00	5.4E+01	0.0	
68	4.628415E-05	2.3E+06	0.0		69	3.249577E+00	3.2E+01	0.0	
70	-2.840604E-04	3.5E+04	0.0		71	2.521879E+01	3.3E+00	0.0	
72	2.070572E+01	4.2E+00	0.0		73	4.159457E-04	2.6E+05	0.0	
74	3.266841E+01	2.3E+00	0.0		75	6.602815E-04	1.6E+05	0.0	
76	-4.607049E-04	2.1E+04	0.0		77	4.014250E+01	1.7E+00	0.0	
78	8.378482E-04	1.9E+04	0.0		79	1.319516E-03	1.2E+04	0.0	
81	5.228602E-01	2.1E+02	0.0		82	6.479515E-02	1.7E+03	0.0	
83	4.837690E-01	2.2E+02	0.0		84	2.306435E-02	4.6E+03	0.0	
89	2.350796E+01	3.6E+00	0.0		90	3.267276E+01	2.3E+00	0.0	
91	4.350659E+01	1.5E+00	0.0		92	3.260153E+01	2.3E+00	0.0	

HCGS-20 GONDOLA ASSEMBLY
RUN 1.01, 1-POINT, LIMIT LOAD, 50-40 DIST., 590 PSF

SUBCASE 1

S T R E S S E S   I N   Q U A D R I L A T E R A L   E L E M E N T S   (Q U A D 4)

ELEMENT ID.	FIBRE DISTANCE	STRESSES IN ELEMENT COORD SYSTEM NORMAL-X	NORMAL-Y	SHEAR-XY	PRINCIPAL STRESSES (ZERO SHEAR) ANGLE	MAJOR	MINOR	MAX SHEAR
93	-2.000000E-02	-4.187094E-02	-2.633702E-02	2.965457E-01	45.7502	2.625435E-01	-3.307514E-01	2.966474E-01
	2.000000E-02	-4.187094E-02	-2.633702E-02	2.965457E-01	45.7502	2.625435E-01	-3.307514E-01	2.966474E-01
94	-2.000000E-02	4.674447E-03	-3.679310E-02	2.969529E-01	43.0030	2.816165E-01	-3.137352E-01	2.976758E-01
	2.000000E-02	4.674447E-03	-3.679310E-02	2.969529E-01	43.0030	2.816165E-01	-3.137352E-01	2.976758E-01
95	-2.000000E-02	1.778917E-02	-4.982676E-02	2.203064E-01	40.6378	2.068665E-01	-2.389041E-01	2.228853E-01
	2.000000E-02	1.778917E-02	-4.982676E-02	2.203064E-01	40.6378	2.068665E-01	-2.389041E-01	2.228853E-01
96	-2.000000E-02	2.011243E-02	-5.826896E-02	1.182112E-01	35.8290	1.054601E-01	-1.436166E-01	1.245384E-01
	2.000000E-02	2.011243E-02	-5.826896E-02	1.182112E-01	35.8290	1.054601E-01	-1.436166E-01	1.245384E-01
97	-2.000000E-02	2.678545E-03	-6.154875E-02	1.557882E-02	12.9394	6.257840E-03	-6.512804E-02	3.569294E-02
	2.000000E-02	2.678545E-03	-6.154875E-02	1.557882E-02	12.9394	6.257840E-03	-6.512804E-02	3.569294E-02
98	-2.000000E-02	-4.877587E-03	1.395854E-03	-3.531002E-02	-47.5382	3.370820E-02	-3.718993E-02	3.544907E-02
	2.000000E-02	-4.877587E-03	1.395854E-03	-3.531002E-02	-47.5382	3.370820E-02	-3.718993E-02	3.544907E-02
99	-2.000000E-02	-2.485321E-04	1.132232E-04	-1.148363E-01	-45.0451	1.147688E-01	-1.149041E-01	1.148365E-01
	2.000000E-02	-2.485321E-04	1.132232E-04	-1.148363E-01	-45.0451	1.147688E-01	-1.149041E-01	1.148365E-01
100	-2.000000E-02	1.157078E-03	-1.529489E-02	-2.463974E-01	-44.0439	2.394657E-01	-2.536035E-01	2.465346E-01
	2.000000E-02	1.157078E-03	-1.529489E-02	-2.463974E-01	-44.0439	2.394657E-01	-2.536035E-01	2.465346E-01
101	-2.000000E-02	8.670150E-03	-3.823438E-02	-3.563365E-01	-43.1173	3.423253E-01	-3.718895E-01	3.571074E-01
	2.000000E-02	8.670150E-03	-3.823438E-02	-3.563365E-01	-43.1173	3.423253E-01	-3.718895E-01	3.571074E-01
102	-2.000000E-02	5.727492E-02	-6.452973E-02	-4.236746E-01	-40.9099	4.244021E-01	-4.316569E-01	4.280295E-01
	2.000000E-02	5.727492E-02	-6.452973E-02	-4.236746E-01	-40.9099	4.244021E-01	-4.316569E-01	4.280295E-01
103	-2.000000E-02	.347441E-02	1.871988E-02	2.638942E-01	45.2847	2.800044E-01	-2.478101E-01	2.639073E-01
	2.000000E-02	.347441E-02	1.871988E-02	2.638942E-01	45.2847	2.800044E-01	-2.478101E-01	2.639073E-01
104	-2.000000E-02	4.720228E-02	2.988655E-03	1.611544E-01	41.0945	1.877591E-01	-1.375681E-01	1.626636E-01
	2.000000E-02	4.720228E-02	2.988655E-03	1.611544E-01	41.0945	1.877591E-01	-1.375681E-01	1.626636E-01
105	-2.000000E-02	- [illegible]313E-02	-8.924678E-03	3.358785E-02	23.0404	7.004831E-02	-2.320986E-02	4.662909E-02
	2.000000E-02	[illegible]6313E-02	-8.924678E-03	3.358785E-02	23.0404	7.004831E-02	-2.320986E-02	4.662909E-02
106	-2.000000E-02	1.837139E-02	-3.642394E-03	-1.324151E-01	-42.6241	1.402362E-01	-1.255073E-01	1.328717E-01
	2.000000E-02	1.837139E-02	-3.642394E-03	-1.324151E-01	-42.6241	1.402362E-01	-1.255073E-01	1.328717E-01
107	-2.000000E-02	6.690044E-03	2.187699E-02	2.182252E-01	45.9964	2.326408E-01	-2.040738E-01	2.183573E-01
	2.000000E-02	6.690044E-03	2.187699E-02	2.182252E-01	45.9964	2.326408E-01	-2.040738E-01	2.183573E-01
108	-2.000000E-02	3.743480E-02	6.381715E-03	8.689822E-02	39.9348	1.101827E-01	-6.636617E-02	8.827442E-02
	2.000000E-02	3.743480E-02	6.381715E-03	8.689822E-02	39.9348	1.101827E-01	-6.636617E-02	8.827442E-02

MEGS-20 GONDOLA ASSEMBLY
RUN 1.01, 1-POINT, LIMIT LOAD, 60-40 DIST., 690 PSF

SUBCASE 1

S T R E S S E S   I N   Q U A D R I L A T E R A L   E L E M E N T S   (Q U A D 4)

ELEMENT ID.	FIBRE DISTANCE	STRESSES IN ELEMENT COORD SYSTEM NORMAL-X	NORMAL-Y	SHEAR-XY	PRINCIPAL STRESSES (ZERO SHEAR) ANGLE	MAJOR	MINOR	MAX SHEAR
109	-2.000000E-02	5.694761E-02	-4.034975E-03	-3.967968E-02	-26.2291	7.649747E-02	-2.358864E-02	5.004316E-02
	2.000000E-02	5.694761E-02	-4.034975E-03	-3.967968E-02	-26.2291	7.649747E-02	-2.358864E-02	5.004316E-02
110	-2.000000E-02	-9.812867E-03	-1.449037E-02	-2.622258E-01	-44.7445	2.500851E-01	-2.743875E-01	2.622363E-01
	2.000000E-02	-9.812867E-03	-1.449037E-02	-2.622258E-01	-44.7445	2.500851E-01	-2.743875E-01	2.622363E-01
111	-2.000000E-02	2.111828E-02	6.806673E-02	9.747292E-02	51.7703	1.448522E-01	-5.566721E-02	1.002597E-01
	2.000000E-02	2.111828E-02	6.806673E-02	9.747292E-02	51.7703	1.448522E-01	-5.566721E-02	1.002597E-01
112	-2.000000E-02	3.918581E-02	5.625792E-02	-1.627333E-02	-58.8395	6.609809E-02	2.934564E-02	1.837622E-02
	2.000000E-02	3.918581E-02	5.625792E-02	-1.627333E-02	-58.8395	6.609809E-02	2.934564E-02	1.837622E-02
113	-2.000000E-02	6.623309E-02	5.428396E-02	-1.296636E-01	-43.6842	1.900440E-01	-6.955698E-02	1.298005E-01
	2.000000E-02	6.623309E-02	5.428396E-02	-1.296636E-01	-43.6842	1.900440E-01	-6.955698E-02	1.298005E-01
114	-2.000000E-02	2.168220E-01	4.480219E-02	-3.424122E-01	-37.9498	4.838619E-01	-2.222370E-01	3.530494E-01
	2.000000E-02	2.168220E-01	4.480219E-02	-3.424122E-01	-37.9498	4.838619E-01	-2.222370E-01	3.530494E-01
115	-2.000000E-02	2.215825E-02	7.894608E-02	4.506801E-02	61.1060	1.038186E-01	-2.714522E-03	5.326669E-02
	2.000000E-02	2.215825E-02	7.894608E-02	4.506801E-02	61.1060	1.038186E-01	-2.714522E-03	5.326669E-02
116	-2.000000E-02	3.233518E-02	6.564474E-02	-1.041277E-01	-49.5436	1.544412E-01	-5.646124E-02	1.054512E-01
	2.000000E-02	3.233518E-02	6.564474E-02	-1.041277E-01	-49.5436	1.544412E-01	-5.646124E-02	1.054512E-01
117	-2.000000E-02	6.312434E-02	6.454405E-02	-2.325916E-01	-45.0874	2.964269E-01	-1.687585E-01	2.325927E-01
	2.000000E-02	6.312434E-02	6.454405E-02	-2.325916E-01	-45.0874	2.964269E-01	-1.687585E-01	2.325927E-01
118	-2.000000E-02	1.702342E-01	3.818513E-02	-3.481584E-01	-39.6310	4.585732E-01	-2.501538E-01	3.543635E-01
	2.000000E-02	1.702342E-01	3.818513E-02	-3.481584E-01	-39.6310	4.585732E-01	-2.501538E-01	3.543635E-01

S T R E S S E S   I N   T R I A N G U L A R   E L E M E N T S   (T R I A 3)

ELEMENT ID.	FIBRE DISTANCE	STRESSES IN ELEMENT COORD SYSTEM NORMAL-X	NORMAL-Y	SHEAR-XY	PRINCIPAL STRESSES (ZERO SHEAR) ANGLE	MAJOR	MINOR	MAX SHEAR
119	-2.000000E-02	-2.420934E-02	-1.406832E-02	2.640159E-01	45.5501	2.449258E-01	-2.832034E-01	2.640646E-01
	2.000000E-02	-2.420934E-02	-1.406832E-02	2.640159E-01	45.5501	2.449258E-01	-2.832034E-01	2.640646E-01
120	-2.000000E-02	-1.539808E-01	8.168805E-02	3.125599E-01	55.3282	2.978875E-01	-3.701802E-01	3.340339E-01
	2.000000E-02	-1.539808E-01	8.168805E-02	3.125599E-01	55.3282	2.978875E-01	-3.701802E-01	3.340339E-01
121	-2.000000E-02	-2.624965E-02	-1.065087E-02	3.605556E-01	45.6196	3.421897E-01	-3.790902E-01	3.606399E-01
	2.000000E-02	-2.624965E-02	-1.065087E-02	3.605556E-01	45.6196	3.421897E-01	-3.790902E-01	3.606399E-01
122	-2.000000E-02	-1.161326E-02	-6.259956E-03	1.986059E-01	45.3857	1.898873E-01	-2.077605E-01	1.988239E-01
	2.000000E-02	-1.161326E-02	-6.259956E-03	1.986059E-01	45.3857	1.898873E-01	-2.077605E-01	1.988239E-01
123	-2.000000E-02	4.053821E-02	8.795512E-02	1.643758E-01	49.1037	2.303235E-01	-1.018301E-01	1.660768E-01
	2.000000E-02	4.053821E-02	8.795512E-02	1.643758E-01	49.1037	2.303235E-01	-1.018301E-01	1.660768E-01
124	-2.000000E-02	-4.039030E-03	7.707925E-03	1.349757E-01	46.2458	1.369379E-01	-1.332690E-01	1.351034E-01
	2.000000E-02	-4.039030E-03	7.707925E-03	1.349757E-01	46.2458	1.369379E-01	-1.332690E-01	1.351034E-01

7.2 Superstructure Loads and Stress Analyses

7.2.1 Loads. Table A-3 presents a summary of the maximum loads acting on the members of the superstructure for the HEGS-20 module. Loads for the single-point suspension system were obtained from the NASTRAN results. Maximum loads for the longitudinal and lateral racking conditions and the stacking condition were obtained by using the principles of static equilibrium. The critical tension and compression loads acting on the superstructure members are also presented.

7.2.2 Stress Analysis.

7.2.2.1 Corner Columns -

7.2.2.1.1 Tubing -

Material	6061-T6 Aluminum Tubing
Limit Loads	8.6 kips, - 16.0 kips
Size	3-3/4 in. OD x .125 in. thick

$A = 1.424\ \text{in.}^2$ $\quad I = 2.341\ \text{in.}^4$ $\quad S = 1.248$ $\quad r = 1.282\ \text{in.}$

7.2.2.1.1.1 Buckling at center of tube - From Figure 1.6.3.2, Reference 4:

$$B = \frac{L'/r}{\pi\sqrt{E/F_{co}}} \qquad \text{where } L' = \frac{L}{\sqrt{C}}$$

For simply supported ends, C = 1 and L' = L

Column length = 87.19 in.

$$B = \frac{87.19/1.282}{\pi\sqrt{10{,}000/35.0}} = 1.281$$

$$R_A = 1 - .385B = 1 - .385\ (1.281) = .507$$

$$F_c = R_A\ F_{co} = .507\ (35.0) = 17.74\ \text{ksi}$$

Ultimate Compressive Stress, $f_u = \frac{1.5\ P_y}{A}$

$$f_u = \frac{1.5\ (-\ 16.0)}{1.424} = 16.85\ \text{ksi}$$

$$MS_u = \frac{17.74}{16.85} - 1 = \underline{.053}$$

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F

TABLE A-3. MAXIMUM SUPERSTRUCTURE LIMIT LOADS FOR HEGS-20

MEMBER	1-POINT SUSPENSION (KIPS)	.6g RACKING		2-HIGH STACKING (1.0g) (KIPS)	CRITICAL LOAD	
		LONGITUDINAL (KIPS)	LATERAL (KIPS)		TENSION (KIPS)	COMPRESSION (KIPS)
Corner Column	8.6	- 6.2	- 16.0	- 9.0	8.6	- 16.0
Center Column	0	- 6.2	0	0	0	- 6.2
Upper Side	- 23.3	- 17.5	- 2.5	- 2.5	0	- 23.3
Upper End	- 4.0	- 2.0	- 17.0	- 2.0	0	- 17.0
Upper Center Lateral	- .2	- 3.9	- 3.9	- 3.9	0	- 3.9
Upper Diagonal	.2	3.2	3.2	3.2	3.2	0
Side Diagonal	20.1	9.7	0	0	20.1	0
End Diagonal	1.6	0	21.9	0	21.9	0

7.2.2.1.1.2 Compression yield stress at tube ends (heat-affected zone) -

$$f_{cy} = \frac{P_y}{A} = \frac{-16.0}{1.424} = 11.24 \text{ ksi}$$

$$F_{cy} = 20 \text{ ksi}$$

$$MS_{cy} = \frac{20.0}{11.24} - 1 = \underline{.78}$$

7.2.2.1.1.3 Compressive ultimate stress at tube ends (heat-affected zone) -

Ultimate Compression Load, $P_u = 1.5\ P_y = 1.5\ (16.0) = 24$ kips

$$f_{cu} = \frac{P_u}{A} = \frac{24.0}{1.424} = 16.85 \text{ ksi}$$

$$F_{cu} = 24 \text{ ksi}$$

$$MS_{cu} = \frac{24.0}{16.85} - 1 - \underline{.42}$$

7.2.2.1.2 Column End Fitting Lug -

Material	6061-T6 Aluminum Bar
Limit Loads	8.6 kips, 16.0 kips

7.2.2.1.2.1 Lug shearout -

$$A_s = 2\ (2)\ (.500)\ (5.00 - 3.90 - 3.75)$$

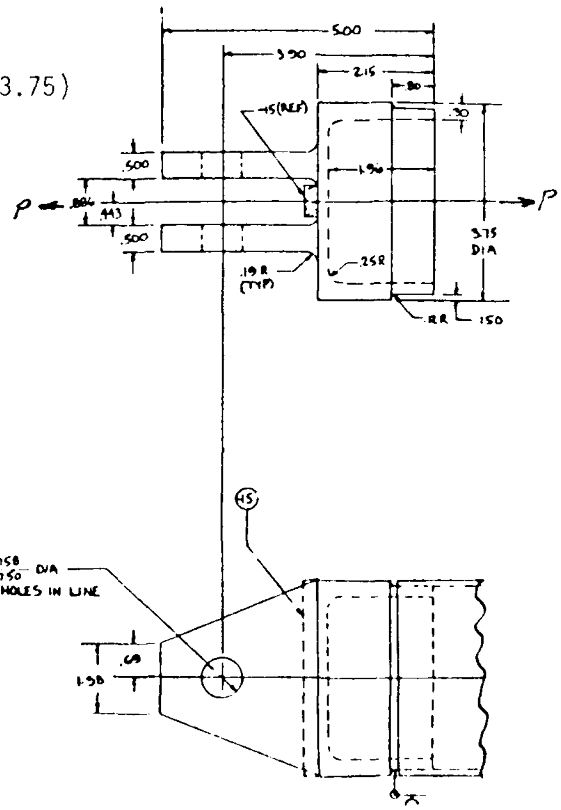
$$A_s = 1.45 \text{ in.}^2$$

$$f_{su} = \frac{1.5\ P_{LIMIT}}{A_s} = \frac{1.5\ (8.6)}{1.45}$$

$$f_{su} = 8.90 \text{ ksi}$$

$$F_{su} = 27.0 \text{ ksi}$$

$$MS_{su} = \frac{27.0}{8.90} - 1 = \underline{2.03}$$



7.2.2.1.2.2 Bearing -

$$A_{br} = 2\ (.500)\ (.750) = .750\ \text{in.}^2$$

$$F_{bry} = \frac{P_{LIMIT}}{A_{br}} = \frac{16.0}{.75}$$

$$f_{bry} = 21.33\ \text{ksi}$$

$$F_{bry} = 56\ \text{ksi}$$

$$MS_{bry} = \frac{56.0}{21.33} - 1 = \underline{1.62}$$

7.2.2.1.2.3 Tension in net section -

$$P_{LIMIT} = 8.6\ \text{kips}$$

$$A_t = 2\ (2)\ (.500)\ (.867) = 1.734\ \text{in.}^2$$

$$f_{tu} = \frac{1.5\ P_{LIMIT}}{A_t} = \frac{1.5\ (8.6)}{1.734} = 7.44\ \text{ksi}$$

$$F_{tu} = 42.0\ \text{ksi}$$

$$MS_{tu} = \frac{42.0}{7.44} - 1 = \underline{1.74}$$

7.2.2.2 Column Attach Pin, MS20392-10C65 -

Material: Alloy Steel

$F_{tu} = 125$ ksi, $F_{ty} = 103$ ksi, $F_{su} = 75$ ksi

Pin diameter: .747 in.

$$\text{Double Shear Area} = \frac{2\pi d^4}{4} = \frac{2\pi\ (.747)^2}{4} = .876\ \text{in.}^2$$

$$P_u = 1.5\ P_{LIMIT} = 1.5\ (16.0) = 24.0\ \text{kips}$$

$$f_{su} = \frac{P_u}{A_s} = \frac{24.0}{.876} = 27.40\ \text{ksi}$$

$$F_{su} = 75\ \text{ksi}$$

$$MS_{su} = \frac{75.0}{27.40} - 1 = 1.74$$

7.2.2.3 Lower Corner Fitting Lug -

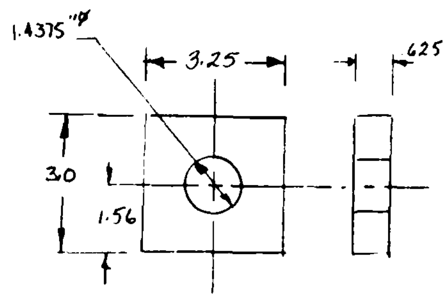
Material — 5456 - H321 Aluminum plate

Limit Load — 8.6 kips, - 16.0 kips

7.2.2.3.1 Shearout -

$$A_s = 2\ (.625)\ (3.0 - 1.56 - \frac{1.4375}{2}) = .902\ \text{in.}^2$$

$$f_{sy} = \frac{P_{LIMIT}}{A_s} = \frac{8.6}{.902} = 9.53\ \text{ksi}$$



$$F_{sy} = 15.0\ \text{ksi}$$

$$M_{sy} = \frac{15.0}{9.53} - 1 = \underline{.57}$$

7.2.2.3.2 Tension -

$$A_T = (3.25 - 1.4375)\ (.625) = 1.133\ \text{in.}^2$$

$$f_{ty} = \frac{P_{LIMIT}}{A_{br}} = \frac{16.0}{.898} = 17.82\ \text{ksi}$$

$$F_{ty} = 26.0\ \text{ksi}$$

$$MS_{ty} = \frac{26.0}{7.59} - 1 = \underline{2.42}$$

7.2.2.3.3 Bearing -

$$A_{br} = 1.4375\ (.625) = .898\ \text{in.}^2$$

$$f_{bry} = \frac{P_{LIMIT}}{A_{br}} = \frac{16.0}{.898} = 17.82\ \text{ksi}$$

$$F_{bry} = 44.0\ \text{ksi}$$

$$MS_{bry} = \frac{44.0}{17.82} - 1 = \underline{1.47}$$

7.2.2.4 Center Column -

Tube Material	6061-T6 Aluminum tubing
Lower End Fitting Material	6061-T6 Aluminum bar
Upper Fitting Material	17-4PH Cond 1025
Limit Load	- 6.2 kips

7.2.2.4.1 Center Portion of Tube (Buckling Analysis) -

Tube size 3-3/4 in. OD x .125 in. thick

$A = 1.424 \text{ in.}^2$ $I = 2.341 \text{ in.}^4$ $S = 1.248 \text{ in.}^3$ $r = 1.282 \text{ in.}$

Effective Length = 88.48 in.

$$B = \frac{L/r}{\pi\sqrt{E/F_{co}}} = \frac{88.48/1.282}{\pi\sqrt{10{,}000/35.0}} = 1.30$$

$$R_a = 1 - .385\, B = 1 - .385\,(1.30) = .50$$

$$F_c = R_a\, F_{co} = .50\,(35.0) = 17.5 \text{ ksi}$$

$$f_{cu} = \frac{1.5\, P_{LIMIT}}{A} = \frac{1.5\,(-\,6.2)}{1.424} = -\,6.53 \text{ ksi}$$

$$MS_{cu} = \frac{17.5}{6.53} - 1 = \underline{1.68}$$

7.2.2.4.2 Lower End of Tube (Heat-Affected Zone) -

$$P_u = 1.5\, P_{LIMIT} = 1.5\,(6.2) = 9.3 \text{ kips}$$

$$f_{cu} = \frac{P_u}{A} = \frac{9.3}{1.424} = 6.53 \text{ ksi}$$

$$F_{cu} = 24 \text{ ksi}$$

$$MS_{cu} = \frac{24.0}{6.53} - 1 = 2.68$$

7.2.2.4.3 Threaded Portion of -13 End Fitting -

Material	17-4PH Cond 1025
Thread	1-3/4-8UN-2B

Limit Shear Stress $f_{sy} = \dfrac{2\, P_{LIMIT}}{\pi dh} = \dfrac{2\,(6.2)}{\pi(1.75)\,(1.0)}$

$f_{sy} = 2.26$ ksi

$f_{su} = 1.5\ f_{sy} = 1.5\ (2.26) = 3.39$ ksi

$F_{su} = 90$ ksi

$$MS_{su} = \frac{90.0}{3.39} - 1 = \underline{\text{AMPLE}}$$

7.2.2.5 Upper Structure -

7.2.2.5.1 Upper Sides, -11 -

Material	6061-T6 Aluminum
Size	5 in. Schedule 5 Pipe
Effective Length	99.9 in.
Limit Load	- 23.3

$A = 1.88\ \text{in.}^2$ $I = 6.96\ \text{in.}^4$ $S = 2.5\ \text{in.}^3$ $r = 1.924$ in.

OD = 5.563 in.

7.2.2.5.1.1 Buckling -

$$B = \frac{L/r}{\pi\sqrt{E/F_{co}}} = \frac{99.9/1.924}{\pi\sqrt{10{,}000/35.0}} = .978$$

$$R_A = 1 - .385\ B = 1 - .385\ (.978) = .623$$

$$F_c = R_A\ F_{co} = .623\ (35.0) = 21.83\ \text{ksi}$$

$$f_u = \frac{1.5\ P_{LIMIT}}{A} = \frac{1.5\ (23.3)}{1.88} = 18.59\ \text{ksi}$$

$$MS_{cu} = \frac{21.82}{18.59} - 1 = \underline{.17}$$

7.2.2.5.1.2 Ultimate compression in heat-affected zone -

$$f_{cu} = \frac{1.5\ P_{LIMIT}}{A} = \frac{1.5\ (23.3)}{1.88} = 18.59\ \text{ksi}$$

$F_{cu} = 24.0$ ksi

$$MS_{cu} = \frac{24.0}{18.59} - 1 = \underline{.29}$$

7.2.2.5.2 Upper Ends, -13 -

Material	6061-T6 Aluminum
Size	5 in. Schedule 5 Pipe
Effective Length	76.0 in.
Limit Load	- 17.0 kips

$A = 1.88\ \text{in.}^2 \quad I = 6.96\ \text{in.}^4 \quad S = 2.5\ \text{in.}^3 \quad r = 1.924\ \text{in.}$

OD = 5.563 in.

7.2.2.5.2.1 Buckling -

$$B = \frac{L/r}{\pi\sqrt{E/F_{co}}} = \frac{76.0/1.924}{\pi\sqrt{10,000/35.0}} = .744$$

$$R_A = 1 - .385\ B = 1 - .385\ (.744) = .714$$

$$F_c = R_A\ F_{co} = .714\ (35.0) = 24.99\ \text{ksi}$$

$$f_u = \frac{1.5\ P_{LIMIT}}{A} = \frac{1.5\ (17.0)}{1.88} = 13.56\ \text{ksi}$$

$$MS_{cu} = \frac{24.99}{13.56} - 1 = \underline{.84}$$

7.2.2.5.2.2 Ultimate compression in heat-affected zone -

$$f_{cu} = \frac{1.5\ P_{LIMIT}}{A} = \frac{1.5\ (17.0)}{1.88} = 13.56\ \text{ksi}$$

$$F_{cu} = 24.0\ \text{ksi}$$

$$MS_{cu} = \frac{24.0}{13.56} - 1 = \underline{.77}$$

7.2.2.5.3 Upper Center Lateral, -15 -

Material	6061-T6 Aluminum
Size	5 in. Schedule 5 Pipe
Effective Length	75.70 in.
Limit Load	- 3.9 kips

$A = 1.88\ \text{in.}^2 \quad I = 6.96\ \text{in.}^4 \quad S = 2.5\ \text{in.}^3 \quad r = 1.924\ \text{in.}$

OD = 5.563 in.

7.2.2.5.3.1 Buckling -

$$B = \frac{L/r}{\pi\sqrt{E/F_{co}}} = \frac{75.70/1.924}{\pi\sqrt{10{,}000/35.0}} = .741$$

$$R_A = 1 - .385\ B = 1 - .385\ (.741) = .715$$

$$F_c = R_A\ F_{co} = .715\ (35.0) = 25.02 \text{ ksi}$$

$$f_{cu} = \frac{1.5\ P_{LIMIT}}{A} = \frac{1.5\ (3.9)}{1.88} = 3.11 \text{ ksi}$$

$$MS_{cu} = \frac{25.02}{3.11} - 1 = \underline{7.04}$$

7.2.2.5.3.2 Ultimate compression in heat-affected zone -

$$f_{cu} = \frac{1.5\ P_{LIMIT}}{A} = \frac{1.5\ (3.9)}{1.88} = 3.11 \text{ ksi}$$

$$F_{cu} = 24.0 \text{ ksi}$$

$$MS_{cu} = \frac{24.0}{3.11} - 1 = \underline{6.72}$$

7.2.2.6 Upper Diagonal Assembly - The upper diagonal assembly consists of the Kevlar cable and the upper diagonal fitting assembly. This system will be initially preloaded to approximately 3.2 kips. During operation, no additional load will be applied until the upper frame assembly grossly distorts under severe impact conditions. This system is conservatively designed for an ultimate tensile load of 20 kips.

7.2.2.6.1 Kevlar Cable - The upper diagonal Kevlar cable is certified for a breaking strength of 20.0 kips by Philadelphia Resins Corporation, Montgomeryville, Pennsylvania.

$$MS_u = \frac{20.0}{8.2\ (1.5)} - 1 = \underline{3.17}$$

7.2.2.6.2 Upper Diagonal Fitting Assembly -

Ultimate Design Load = 20 kips

Material 17-4PH Cond 1025 Stainless Steel

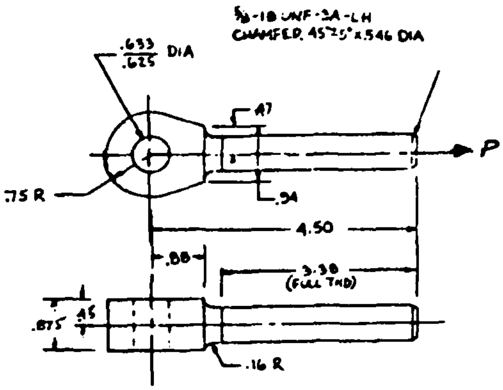
7.2.2.6.2.1 <u>-11 end fitting</u> -

$$A_s = 2\ (.375)\ (.4375) = .328\ \text{in.}^2$$

$$f_{su} = \frac{P_{ULT}}{A_s} = \frac{20.0}{.328} = 60.98\ \text{ksi}$$

$$F_{su} = 90.0\ \text{ksi}$$

$$MS_{su} = \frac{90.0}{60.98} - 1 = \underline{.48}$$



<u>Tension in Lug</u>

$$A_t = .375\ (1.50 - .625) = .328\ \text{in.}^2$$

$$f_{tu} = \frac{P_{ULT}}{A_t} = \frac{20.0}{.328} = 60.98\ \text{ksi}$$

$$F_{tu} = 155.0\ \text{ksi}$$

$$MS_{tu} - \frac{155.0}{60.98} - 1 = \underline{1.54}$$

<u>Tension in Thread Root</u>

Root Diameter = .5554 in.

$$A_{ROOT} = \frac{\pi(.5554)^2}{4} = .242\ \text{in.}^2$$

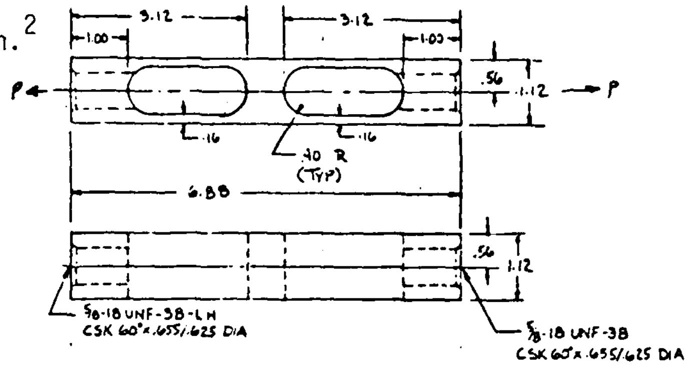
$$f_{tu} = \frac{P_{ULT}}{A_{ROOT}} = \frac{20.0}{.242} = 82.6\ \text{ksi}$$

$$F_{tu} = 155\ \text{ksi}$$

$$MS_{tu} = \frac{155.0}{82.6} - 1 = \underline{.88}$$

7.2.2.6.2.2 <u>-13 center fitting</u> -

<u>Net Tension Section</u>



$A_T = 2\ (.16)\ (1.12) = .358\ \text{in.}^2$

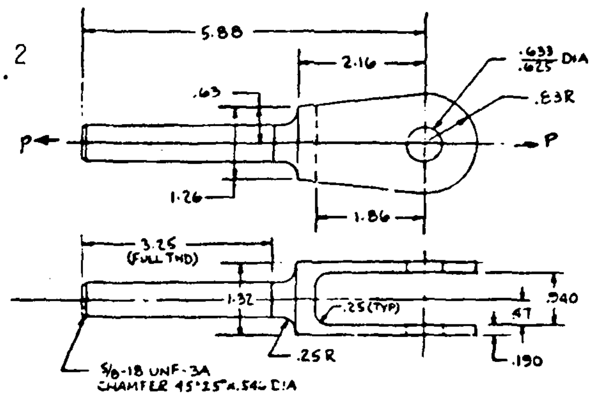
$f_{tu} = \dfrac{P_{ULT}}{A_T} = \dfrac{20.0}{.358} = 55.86$ ksi

$F_{tu} = 155$ ksi

$MS_{tu} = \dfrac{155.0}{55.86} - 1 = \underline{1.77}$

7.2.2.6.2.3 <u>-15 clevis fitting</u> -

<u>Shearout in Lug</u>



$A_s = 2\ (2)\ (.190)\ (.518) = .393\ \text{in.}^2$

$f_{su} = \dfrac{P_{ULT}}{A_s} = \dfrac{20.0}{.393} = 50.89$ ksi

$F_{su} = 90$ ksi

$MS_{su} = \dfrac{90.0}{.393} - 1 = \underline{.77}$

<u>Net Tension in Lug</u>

$A_T = 2\ (1.035)\ (.190) = .393\ \text{in.}^2$

$f_{tu} = \dfrac{P_{ULT}}{A_T} = \dfrac{20.0}{.393} = 50.89$ ksi

$F_{tu} = 155$ ksi

$MS_{tu} = \dfrac{155.0}{50.89} - 1 = \underline{2.04}$

<u>Tension in Thread Root</u>

Root Diameter = .5554 in.

$A_{ROOT} = \dfrac{\pi(.5554)^2}{4} = .242$

$$f_{tu} = \frac{P_{ULT}}{A_{ROOT}} = \frac{20.0}{.242} = 82.\text{ksi}$$

$$F_{tu} = 155 \text{ ksi}$$

$$MS_{tu} = \frac{155.0}{82.6} - 1 = \underline{.88}$$

7.2.2.7 Side/End Diagonal Assembly - The side/end diagonal assembly consists of the Kevlar cable assembly, the side/end diagonal fitting assembly, and the side diagonal link. The maximum limit tensile load acting on the system is 21.9 kips. Ultimate load = 1.5 (21.9) = 32.85 kips.

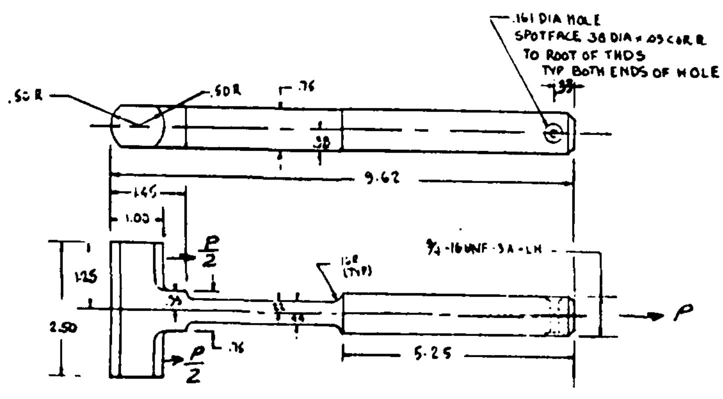
7.2.2.7.1 Kevlar Cable - The side/end diagonal cables are certified for a breaking strength of 58.0 kips by Philadelphia Resins Corporation, Montgomeryville, Pennsylvania.

$$MS_{su} = \frac{58.0}{32.85} - 1 = \underline{.76}$$

7.2.2.7.2 Side/End Diagonal Fitting Assembly -

7.2.2.7.2.1 -13 End Fitting -

Material	17-4PH Cond 1025 Stainless Steel
Limit Load	21.9 kips
Ultimate Load	1.5 (21.9) = 32.85 kips



Tension in Reduced Shank Area

$$A_t = .44\ (.75) = .33\ \text{in.}^2$$

$$f_{tu} = \frac{P_{ULT}}{A_t} = \frac{32.85}{.33} = 99.5\ \text{ksi}$$

$$F_{tu} = 155\ \text{ksi}$$

$$MS_{tu} = \frac{155.0}{99.5} - 1 = \underline{.56}$$

Bending in T-Section

$$I = .0304\ \text{in.}^4 \qquad c = .5$$

$$M_u = \frac{P_u}{2}\,a = \frac{32.85\ (.435)}{2} = 7.14\ \text{kip-in.}$$

$$f_{tu} = \frac{M_c}{I} = \frac{7.14\ (.50)}{.0304} = 117.5\ \text{ksi}$$

$$F_{tu} = 155\ \text{ksi}$$

$$MS_{tu} = \frac{155.0}{117.5} - 1 = \underline{.32}$$

Tension in Thread Root

Thread: 3/4-16UNF-3A-LH

Root Diameter = .6733 in.

Root Area: $A_{ROOT} = \dfrac{\pi(.6733)^2}{4} = .356\ \text{in.}^2$

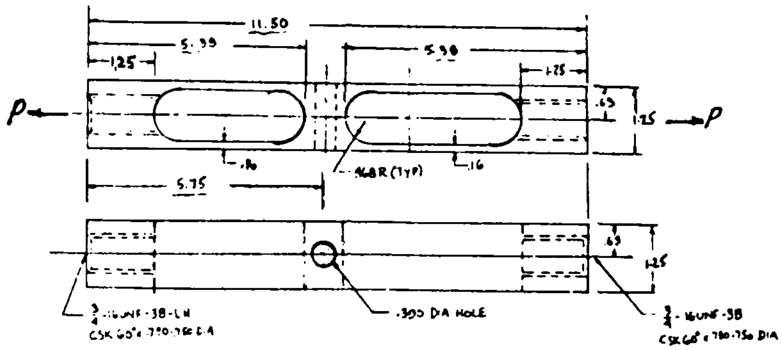
$$f_{tu} = \frac{P_u}{A_{ROOT}} = \frac{32.85}{.356} = 92.28\ \text{ksi}$$

$$F_{tu} = 155\ \text{ksi}$$

$$MS_{tu} - \frac{155.0}{92.28} - 1 = \underline{.68}$$

7.2.2.7.2.2 -11 center fitting -

Material	17-4PH Cond 1025 Stainless Steel
Ultimate Load	32.85 kips



Minimum Tension Section

$$A_t = 2\ (.16)\ (1.25) = .40\ in^2$$

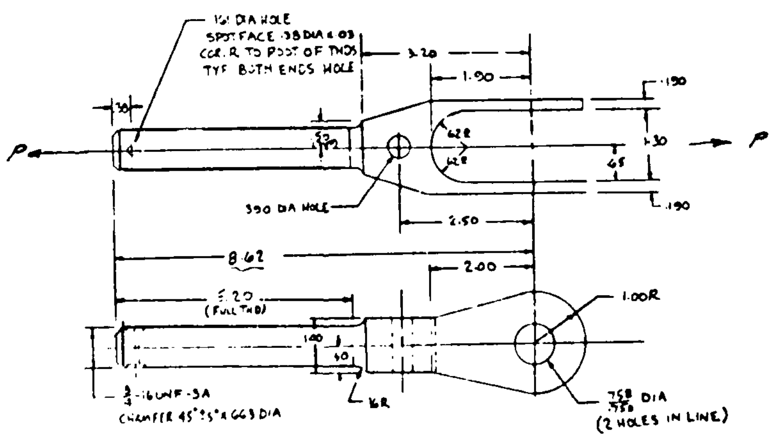
$$f_{tu} = \frac{P_u}{A_t} = \frac{32.85}{.40} = 82.12\ kips$$

$$F_{tu} = 155\ ksi$$

$$MS_{tu} = \frac{155.0}{82.12} - 1 = \underline{.89}$$

7.2.2.7.2.3 -15 end fitting -

Material	17-4PH Cond 1025 Stainless Steel
Ultimate Load	32.85 kips



Shearout in Lugs

$$A_s = 2\ (2)\ (.190)\ (1.0 - .375) = .475 \text{ in.}^2$$

$$f_{su} = \frac{P_u}{A_s} = \frac{32.85}{.475} = 69.16 \text{ ksi}$$

$$F_{su} = 90 \text{ ksi}$$

$$MS_{su} = \frac{90.0}{69.16} - 1 = \underline{.30}$$

Net Tension in Lugs

$$A_T = 2\ (.190)\ (2 - .750) = .475 \text{ in.}^2$$

$$f_{tu} = \frac{P_u}{A_T} = \frac{32.85}{.475} = 69.16 \text{ ksi}$$

$$F_{tu} = 155 \text{ ksi}$$

$$MS_{tu} = \frac{155.0}{69.16} - 1 = \underline{1.24}$$

Tension in Thread Root

Thread: 3/4-16UNF-3A

Root Diameter = .6733 in.

Root Area: $A_{ROOT} = \frac{\pi(.6733)^2}{4} = .356 \text{ in.}^2$

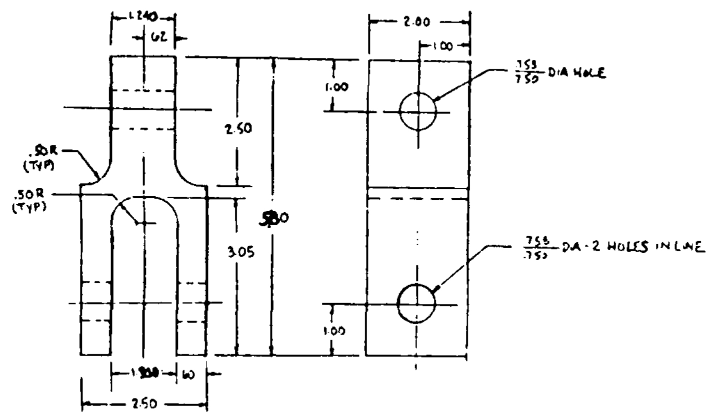
$$f_{tu} = \frac{P_u}{A_{ROOT}} = \frac{32.85}{.356} = 92.28 \text{ ksi}$$

$$F_{tu} = 155 \text{ ksi}$$

$$MS_{tu} = \frac{155.0}{92.28} - 1 = \underline{.68}$$

7.2.2.7.3 Side Diagonal Link

Material	5456-H321 Aluminum Plate
Limit Load	21.9 kips
Ultimate Load	$1.5\ P_{LIMIT} = 1.5\ (21.9) = 32.85$ kips



Shearout in Lug

$$A_s = 2\ (1.240)\ (1.0 - .375) = 1.55\ \text{in.}^2$$

$$f_{sy} = \frac{P_{LIMIT}}{A_s} = \frac{21.9}{1.55} = 14.13\ \text{ksi}$$

$$F_{sy} = 15\ \text{ksi}$$

$$MS_{sy} = \frac{15.0}{14.13} - 1 = \underline{.06}$$

Tension in Lug

$$A_T = 1.240\ (2.0 - .75) = 1.55\ \text{in.}^2$$

$$f_{ty} = \frac{P_{LIMIT}}{A_T} = \frac{21.9}{1.55} = 14.13\ \text{ksi}$$

$$F_{ty} = 26\ \text{ksi}$$

$$MS_{ty} = \frac{26.0}{14.13} - 1 = \underline{.84}$$

Shearout in Clevis

$$A_s = 2\ (2)\ (.6)\ (1.0 - .375) = 1.50 \text{ in.}^2$$

$$f_{sy} = \frac{P_{LIMIT}}{A_s} = \frac{21.9}{1.50} = 14.6 \text{ ksi}$$

$$F_{sy} = 15.0 \text{ ksi}$$

$$MS_{sy} = \frac{15.0}{14.6} - 1 = \underline{.03}$$

Tension in Clevis

$$A_t = 2\ (.60)\ (2.0 - .75) = 1.50 \text{ in.}^2$$

$$f_{ty} = \frac{P_{LIMIT}}{A_t} = \frac{21.9}{1.5} = 14.6$$

$$F_{ty} = 26 \text{ ksi}$$

$$MS_{ty} = \frac{26.0}{14.6} - 1 = \underline{.78}$$

7.2.2.8 Upper Diagonal Attach Lugs on Upper Corner Fitting -

Material	5456-H321 Aluminum Plate
Ultimate Design Load	20 kips
Limit Design Load	$\frac{20}{1.5} = 13.3$ kips

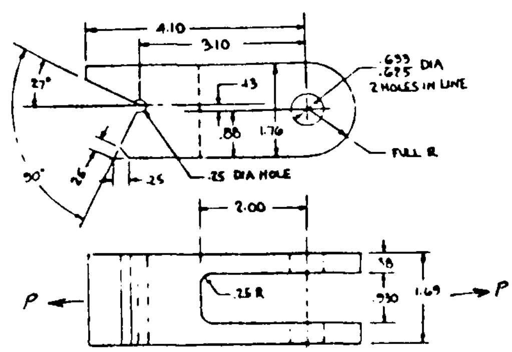
Shearout in Clevis

$$A_s = 2\ (2)\ (.52)\ \left(\frac{1.76}{2} - \frac{.625}{2}\right) = 1.180 \text{ in.}^2$$

$$f_{sy} = \frac{P_{LIMIT}}{A_s} = \frac{13.3}{1.180} = 11.3 \text{ ksi}$$

$$F_{ty} = 15.0 \text{ ksi}$$

$$MS_{sy} = \frac{15.0}{11.3} - 1 = \underline{.33}$$



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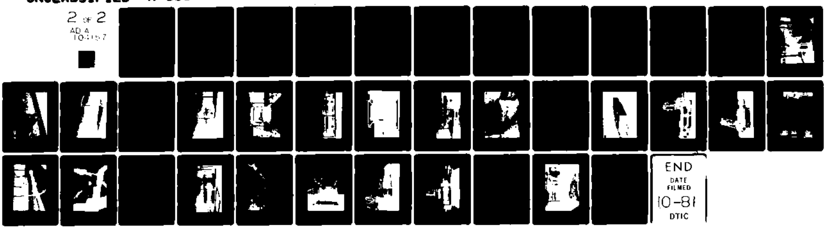

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Tension in Clevis

$A_t = 2\ (.38)\ (1.76 - .625) = .863\ \text{in.}^2$

$$f_{ty} = \frac{P_{LIMIT}}{A_t} = \frac{13.3}{.863} = 15.41\ \text{ksi}$$

$F_{ty} = 26$ ksi

$$MS_{ty} = \frac{26.0}{15.41} - 1 = \underline{.69}$$

7.2.2.9 Side/End Diagonal Attach Lugs on Upper Corner Fitting -

Material	5456-H321 Aluminum Plate
Limit Load	21.9 kips
Ultimate Load	32.85 kips

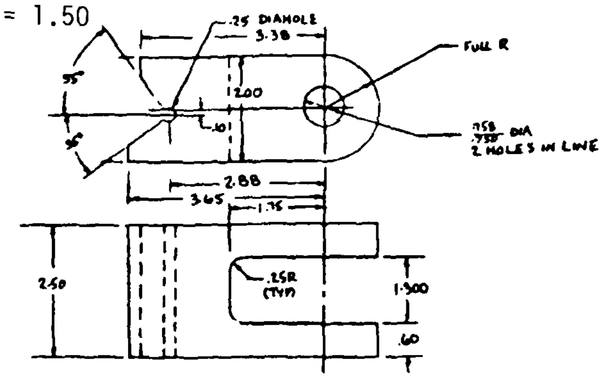
Shearout in Clevis

$A_s = 2\ (2)\ (.60)\ (1.0 - .375) = 1.50$

$$f_{sy} = \frac{P_{LIMIT}}{A_s} = \frac{21.9}{1.50} = 14.6\ \text{ksi}$$

$F_{sy} = 15.0$ ksi

$$MS_{sy} = \frac{15.0}{14.6} - 1 = \underline{.03}$$



Tension in Clevis

$A_t = 2\ (.60)\ (2.00 - .750) = 1.50\ \text{in}^2$

$$f_{ty} = \frac{P_{LIMIT}}{A_t} = \frac{21.9}{1.50} = 14.6\ \text{ksi}$$

$F_{ty} = 26$ ksi

$$MS_{ty} = \frac{26.0}{14.6} - 1 = \underline{.78}$$

7.2.2.10 Upper Diagonal Attach Pins -

Material	Alloy Steel: F_{tu} = 125 ksi, F_{ty} = 103 ksi, F_{su} = 75 ksi
Pins	MS20392-9C47
	MS20392-9C59
Pin Diameter	.625 in.
Design Ultimate Load	20 kips

For Double Shear:

$$A_s = \frac{2\ (\pi)\ (.625)^2}{4} = .614 \text{ in.}^2$$

$$f_{su} = \frac{P_u}{A_s} = \frac{20.0}{.614} = 32.57 \text{ ksi}$$

$$F_{su} = 75 \text{ ksi}$$

$$MS_{su} = \frac{75.0}{32.57} - 1 = \underline{1.30}$$

7.2.2.11 Side/End Diagonal Attach Pins -

Material	Alloy Steel: F_{tu} = 125 ksi, F_{ty} = 103 ksi, F_{su} = 75 ksi
Pins	MS20392-10C59
	MS20392-10C85
Pin Diameter	.75 in.
Limit Load	21.9 kips
Ultimate Load	1.5 (21.9) = 32.85 kips

For Double Shear:

$$A_s = \frac{2\ (\pi)\ (.75)^2}{4} = .884 \text{ in.}^2$$

$$f_{su} = \frac{P_u}{A_s} = \frac{32.85}{.844} = 38.92 \text{ ksi}$$

$$F_{su} = 75 \text{ ksi}$$

$$MS_{su} = \frac{75.0}{38.92} - 1 = \underline{.93}$$

APPENDIX B

TEST RESULTS FOR THE HEGS-20 MODULE

SUMMARY

All acceptance tests were completed successfully with the exception of the dimensional verification. Several dimensions were slightly out of tolerance. This condition was attributed to shrinkage of the unit during welding and, possibly, to the limited accuracy of the inspection procedure. A drawing error accounted for the clear distance between the lower portion of the center columns being smaller than required.

INTRODUCTION

The HEGS-20 module developed for the Applied Technology Laboratory, U. S. Army Research and Technology Laboratories, Fort Eustis, Virginia, under Contract DAAK51-79-C-0036, "Advanced Technology Lightweight Gondola System Experimental Fabrication," is described in the basic section of this report. The testing requirements for this program were composed of two tasks: Task B, Fabrication and Test (Verification Hardware), and Task E, Test (Full-Scale Assemblies). Critical elements/components to be tested during Task B were defined as:

1. Upper corner fitting assembly
2. Lower corner fitting assembly
3. Corner vertical column assembly
4. Side/end diagonal assembly, consisting of the diagonal fitting assembly and the diagonal cable
5. HEGS-20 floor assembly.

An investigation of the test fixtures and procedures required to individually test these components revealed the difficulty in identifying and applying the system of loads acting on components such as the upper and lower corner fittings. It was therefore concluded that the testing of the Task B components would be more accurately accomplished by testing them in the full-scale assembly of Task E. This combined testing permitted the application of the correct loads to each component of the assembly, eliminated the duplicity of test effort, expedited the test program, and reduced the testing costs while still fulfilling the test requirements of Tasks B and E.

The Acceptance Test requirements for the HEGS-20 module were:

1. Dimensional verification
   a. Length
   b. Width
   c. Height
   d. Diagonals: side, end, and top
   e. Corner fittings
   f. Length between centers of apertures in corner fittings
   g. Width between centers of apertures in corner fittings
   h. Effective lateral interior width between corner posts
   i. Effective lateral interior width between center posts
2. Empty weight
3. Rapid connect and disconnect of end and side diagonals, and end and center posts
4. Roll-on, roll-off, and drive-through
5. Rapid, versatile cargo tie-down and release
6. Stacking two-high gondolas loaded to payload capability weight with the most severely loaded condition
7. 1 g floor racking condition
8. 2.3 g limit load single-point suspension lift test
9. 0.6 g lateral racking.

All of the above tasks were performed, except the stacking test. The requirements of the stacking test were met during the performance of the 0.6 g lateral racking test in that the critical component during the stacking test, the corner columns, was more severely loaded during the 0.6 g lateral racking test.

Dimensional Verification

Required measurements were recorded for both HEGS-20 modules fabricated during this program and are presented in Table B-1. For each dimension reported, the actual dimension and the amount of out-of-tolerance are shown. Where out-of-tolerance existed, it is denoted by a "U" for under tolerance or an "A" for above tolerance. In general, the out-of-tolerances noted in this table are small and are not considered detrimental to the functional operation of the modules. The dimensional discrepancy noted for the effective lateral interior width between the lower ends of the center posts, however, is significant and was caused by a combination of a drawing error and the lateral shrinkage of the floor assembly during welding. The drawing has been corrected and the method of dimensioning the locations of the square center post holes has been changed to insure that out-of-tolerance will be eliminated in subsequent units.

Empty Weight

The empty weights for the two HEGS-20 modules were determined by using a calibrated strain gage link attached to a lifting sling and hoist. The resulting weights are:

S/N 1 Empty weight = 1,455 pounds
S/N 2 Empty weight = 1,416 pounds.

The 39-pound difference in weight between S/N 1 and S/N 2 is principally associated with the "learning curve" effect, wherein welding sequences and techniques used during the fabrication of S/N 1 were revised and improved upon during the fabrication of S/N 2.

TABLE B-1. REQUIRED/ACTUAL MEASUREMENTS FOR FABRICATED HEGS-20

DIMENSION	SPECIFICATION	S/N 1		S/N 2	
		ACTUAL	REMARKS	ACTUAL	REMARKS
a. Length	19 ft-10.50 $^{+0}_{-.25}$ in.				
1. Upper					
Right		19 ft-10.373 in.		19 ft-10.375 in.	
Left		19 ft-10.500 in.		19 ft-10.438 in.	
2. Lower					
Right		19 ft-10.438 in.		19 ft-10.312 in.	
Left		19 ft-10.438 in.		19 ft-10.312 in.	
b. Width	8 ft-0 $^{+0}_{-.18}$ in.				
1. Upper					
Forward		7 ft-11.75 in.	.070 U	7 ft-11.781 in.	.039 U
Aft		7 ft-11.75 in.	.070 U	7 ft-11.812 in.	.008 U
2. Lower					
Forward		7 ft-11.875 in.		7 ft-11.781 in.	.039 U
Aft		7 ft-11.813 in.	.070 U	7 ft-11.750 in.	.070 U
c. Height	8 ft-6.5 $^{+0}_{-.75}$ in.				
1. Forward Right		8 ft-5-3/4 in.		8 ft-6.0 in.	
2. Forward Left		8 ft-5-15/16 in.		8 ft-	
3. Aft Right		8 ft-5-13/16 in.		8 ft-6.0 in.	
4. Aft Left		8 ft-5-15/16 in.		8 ft-5-15/16 in.	
d. Diagonals					
1. Sides	Δ = .50 in.				
Right		.188 in.		.052 in.	
Left		.188 in.		.062 in.	
2. Ends	Δ = .50 in.				
Forward		.25 in.		.187 in.	
Aft		.25 in.		0 in.	
3. Top	Δ = .375 in.	.156 in.		.625 in.	.25 A

TABLE B-1. REQUIRED/ACTUAL MEASUREMENTS FOR FABRICATED HEGS-20 (continued)

DIMENSION	SPECIFICATION	S/N 1 ACTUAL	S/N 1 REMARKS	S/N 2 ACTUAL	S/N 2 REMARKS
e. Corner Fittings					
1. Center of Aperture to End	$4^{+0}_{-1/16}$ in.				
Upper					
Forward Right		3.979 in.		3.981 in.	
Forward Left		3.981 in.		3.988 in.	
Aft Right		3.975 in.		3.998 in.	
Aft Left		3.974 in.		3.976 in.	
2. Center of Aperture to Side	$3\text{-}1/2^{+0}_{-1/16}$ in.				
Upper					
Forward Right		3.466 in.		3.480 in.	
Forward Left		3.489 in.		3.484 in.	
Aft Right		3.493 in.		3.483 in.	
Aft Left		3.458 in.		3.478 in.	
3. Thickness of Aperture Plate	$1\text{-}1/8^{+0}_{-1/16}$ in.				
Upper					
Forward Right		1.123 - 1.122 in.		1.125 - 1.138 in.	
Forward Left		1.123 - 1.120 in.		1.121 - 1.120 in.	
Aft Right		1.121 - 1.123 in.		1.122 - 1.122 in.	
Aft Left		1.121 - 1.123 in.		1.121 - 1.126 in.	
Lower					
Forward Right		1.135 - 1.137 in.	.010-.012 A	1.039 - 1.037 in.	.024-.036 U
Forward Left		1.135 - 1.137 in.	.011-.012 A	1.002 - 1.008 in.	.061-.055 U
Aft Right		1.135 - 1.137 in.	.009-.012 A	1.046 - 1.025 in.	.017-.038 U
Aft Left		1.146 - 1.139 in.	.021-.014 A	1.038 - 1.032 in.	.025-.031 U

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TABLE B-1. REQUIRED/ACTUAL MEASUREMENTS FOR FABRICATED HEGS-20 (continued)

DIMENSION	SPECIFICATION	S/N 1 ACTUAL	S/N 1 REMARKS	S/N 2 ACTUAL	S/N 2 REMARKS
4. Length of Aperture	$4\text{-}7/8 {}^{+\,1/16}_{-\,0}$ in.				
Upper					
Forward Right		4.948 in.	.010 A	4.948 in.	.010 A
Forward Left		4.970 in.	.032 A	4.984 in.	.046 A
Aft Right		4.950 in.	.012 A	4.989 in.	.051 A
Aft Left		4.958 in.	.026 A	4.938 in.	
Lower					
Forward Right		4.958 in.		4.927 in.	
Forward Left		4.949 in.	.011 A	4.940 in.	.002 A
Aft Right		4.926 in.		4.928 in.	
Aft Left		4.930 in.		4.946 in.	.008 A
5. Width of Aperture	$2\text{-}1/2 {}^{+\,1/16}_{-\,0}$ in.				
Upper					
Forward Right		2.615 in.	.052 A	2.580 in.	.017 A
Forward Left		2.605 in.	.042 A	2.602 in.	.039 A
Aft Right		2.601 in.	.038 A	2.588 in.	.025 A
Aft Left		2.556 in.		2.576 in.	.013 A
Lower					
Forward Right		2.541 in.		2.545 in.	
Forward Left		2.541 in.		2.546 in.	
Aft Right		2.545 in.		2.545 in.	
Aft Left		2.546 in.		2.545 in.	
f. <u>Length Between Centers of Corner Fitting Apertures</u>	19 ft-2.625 in. 19 ft-1.250 in.				
1. Upper					
Right		19 ft-2.450 in.		19 ft-2.437 in.	
Left		19 ft-2.562 in.		19 ft-2.437 in.	
Lower					
Right		19 ft-2.485 in.		19 ft-2.383 in.	
Left		19 ft-2.469 in.		19 ft-2.374 in.	

TABLE B-1. REQUIRED/ACTUAL MEASUREMENTS FOR FABRICATED HEGS-20 (continued)

DIMENSION	SPECIFICATION	S/N 1 ACTUAL	S/N 1 REMARKS	S/N 2 ACTUAL	S/N 2 REMARKS
g. Width Between Centers of Corner Fitting Apertures	7 ft-5.125 in. 7 ft-4.820 in.				
1. Upper					
Forward		7 ft-4.810 in.	.010 U	7 ft-4.812 in.	.008 U
Aft		7 ft-4.800 in.	.020 U	7 ft-4.875 in.	
2. Lower					
Forward		7 ft-4.938 in.		7 ft-4.854 in.	
Aft		7 ft-4.875 in.		7 ft-4.822 in.	
h. Effective Lateral Interior Width Between Corner Posts	88.0 in. min.				
1. Forward					
Upper		87.938 in.	.062 U	88.000 in.	
Lower		87.938 in.	.062 U	87.875 in.	.125 U
2. Aft					
Upper		87.870 in.	.130 U	88.000 in.	
Lower		87.750 in.	.250 U	87.688 in.	.312 U
i. Effective Lateral Interior Width Between Center Posts					
1. Upper	85.25 in. min.	85.062 in.	.188 U	85.0 in.	.25 U
2. Lower	89.5 in. min.	87.188 in.	2.312 U	87.312 in.	2.188 U

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B

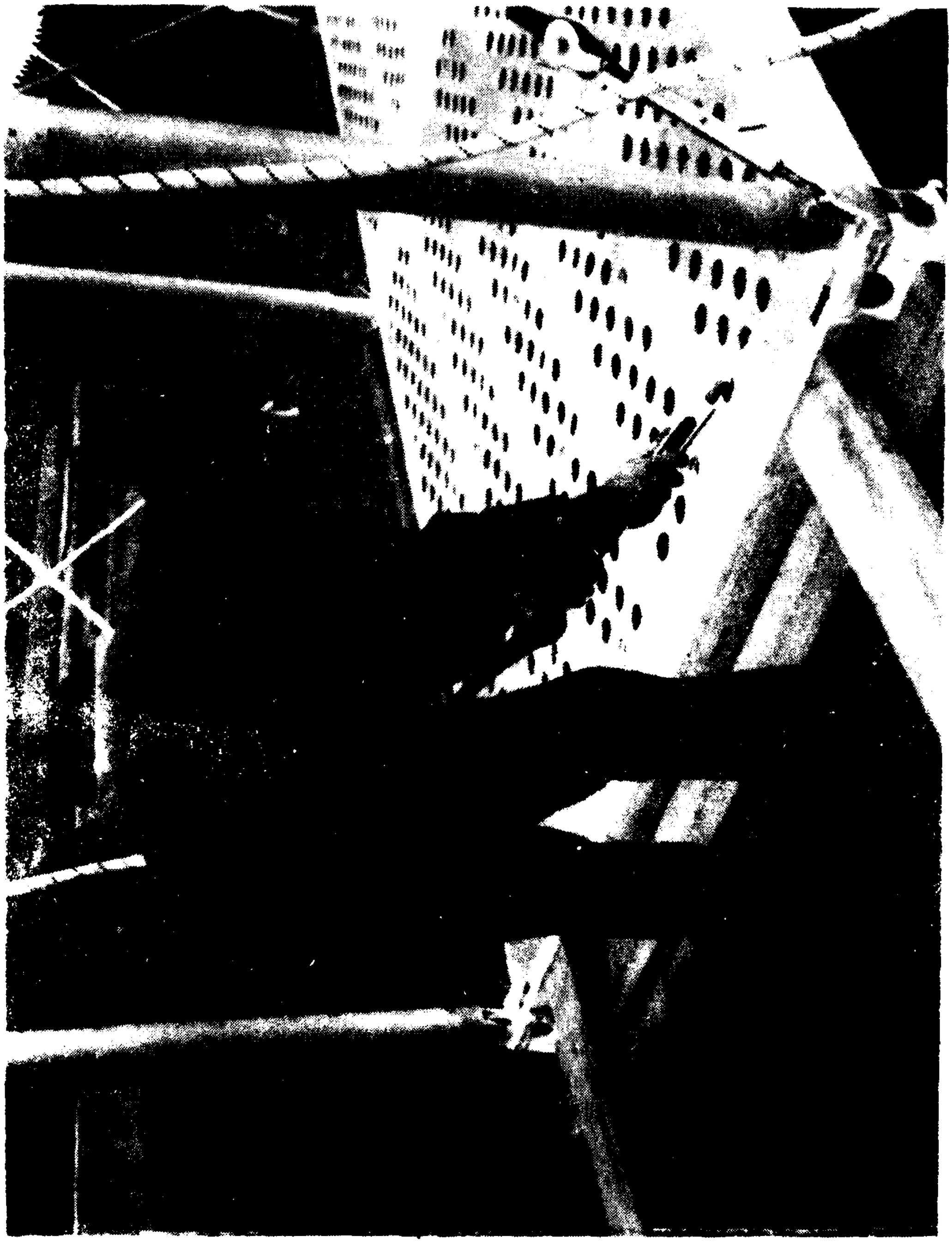
Rapid Connect and Disconnect of End and Side Diagonals, and End and Center Posts

The rapid connect and disconnect of the end and side diagonals and the center post, as well as the corner posts, were demonstrated. Figure B-1 shows the insertion of the T-bar diagonal end fitting into the lower corner fitting slot. Figure B-2 shows the T-bar fittings for the side diagonals and the center columns installed in the center support structure of the floor assembly. Figure B-3 shows the HEGS-20 module prepared for side loading with the side diagonals and the center column removed from one side. Time to connect or disconnect a diagonal is approximately 15 to 20 seconds; a similiar amount of time is required to remove the center column after the side diagonals have been removed. The normal procedure to be followed during side diagonal and center column removal is as follows:

1. Loosen all side diagonals until the T-bar fittings can be twisted 90 degrees and withdrawn from the corner fitting slots and from the center support structure. This requires that the turnbuckle be rotated until the diagonal assembly length has increased approximately 2 inches.
2. Remove center column by rotating the jack screw to shorten the column approximately 1-1/2 inches.

The procedure for installing the center column and the side diagonals is the reverse of the above.

During normal operation of the HEGS-20 module, corner column removal will not be required. When removal is necessary for component repair, etc., the upper and lower column attachment pins are pulled after first removing cotter pins from the ends of the flanged attachment pins.



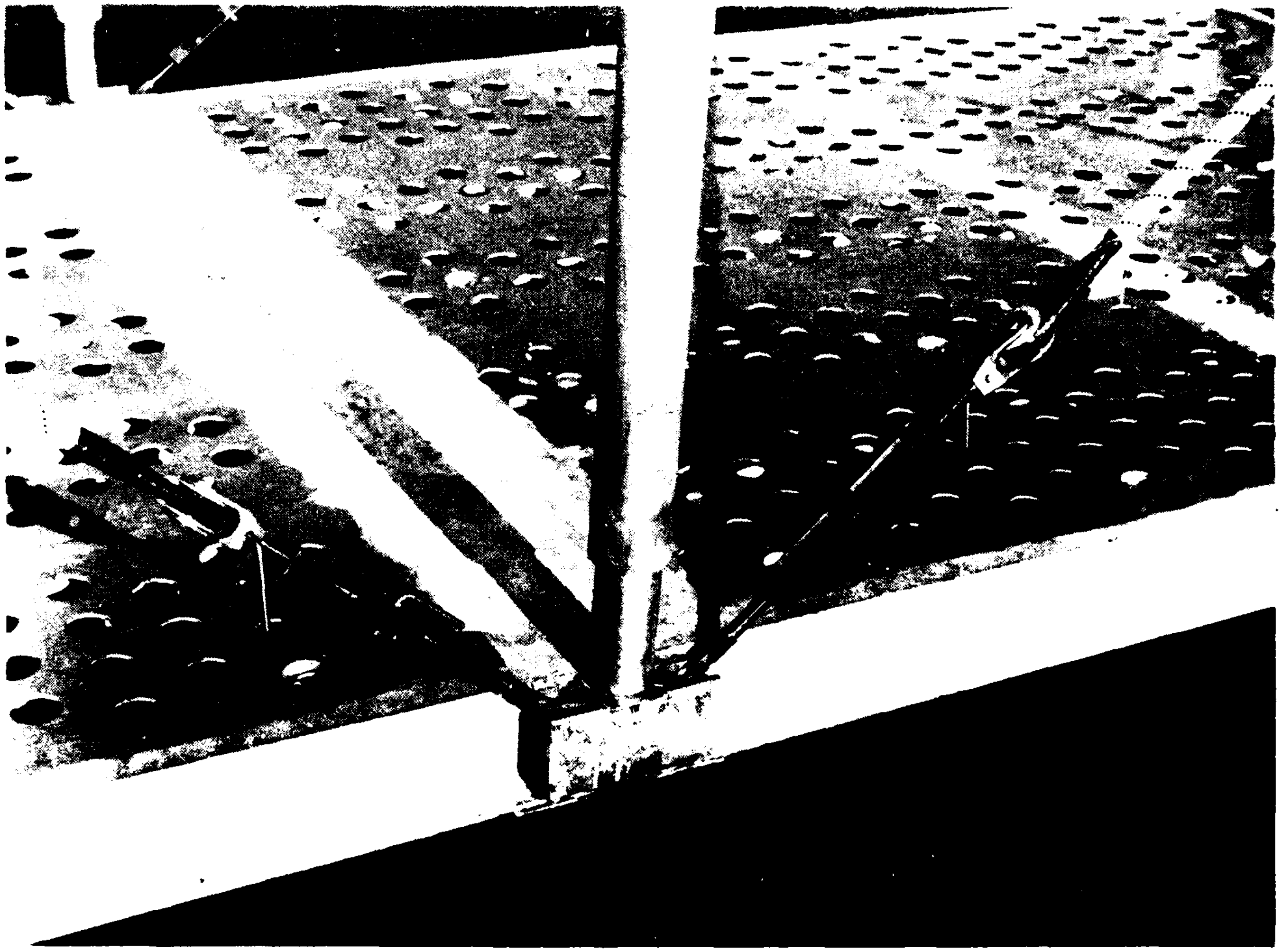


Figure B-2. T-bar diagonal end fitting and center column installed at center of floor structure - HEGS-20.

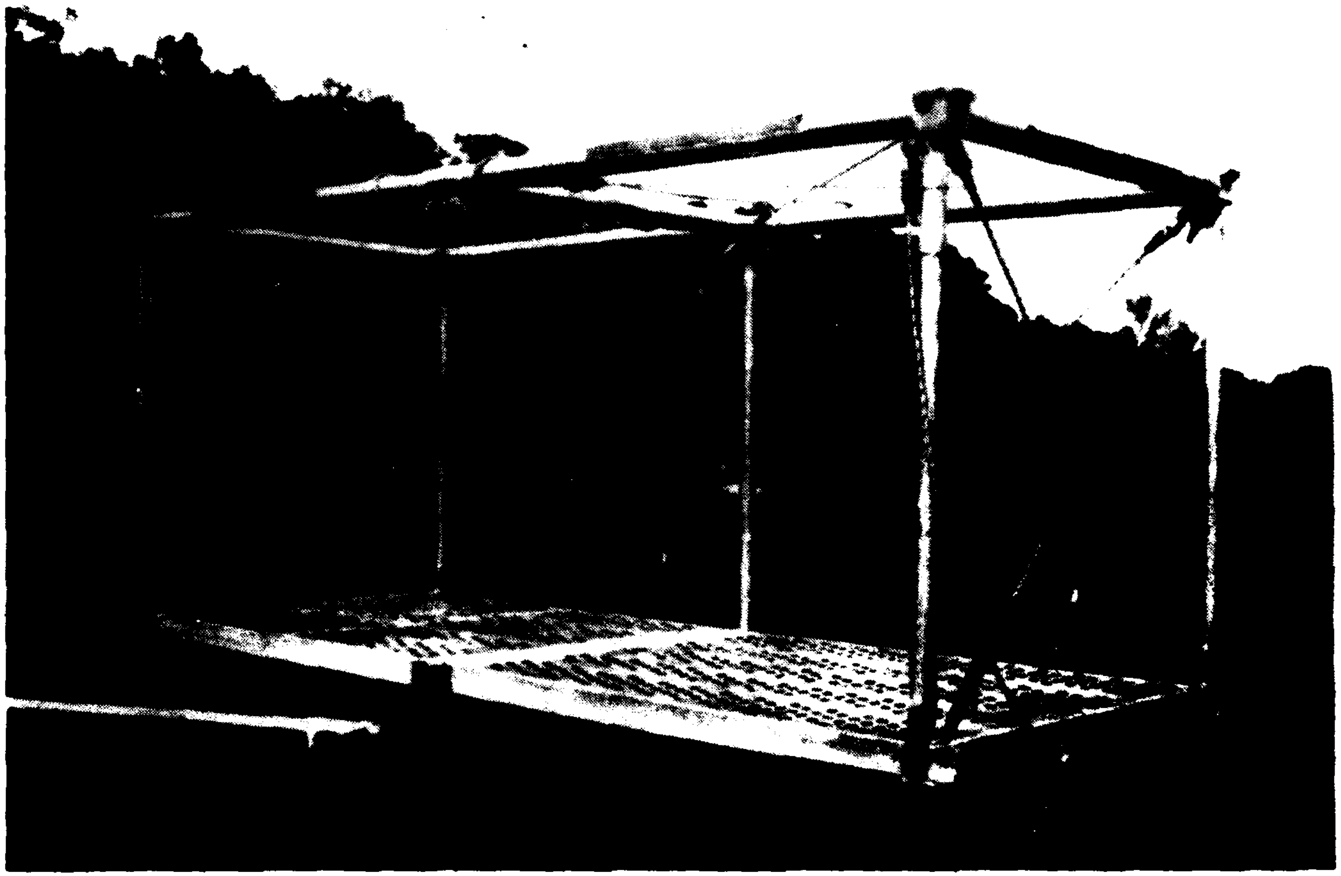


Figure B-3. HEGS-20 module with center column and side diagonals removed.

Roll-on, Roll-off, and Drive-through

The feasibility of driving a truck onto, through, and off the HEGS-20 module was demonstrated, as shown in Figures B-4, B-5, B-6, B-7, and B-8. Figures B-4 and B-5 show the truck entering the module. A ramp was used to assist the two-wheel-drive vehicle onto the module, but none would be required for a military four-wheel-drive vehicle. Figures B-6 and B-7 show the vehicle loaded on the module. Driver egress from the vehicle could be either through the open window or through the door, if one side diagonal was removed to permit the door to open. Figure B-8 shows the vehicle driving off the module without a ramp.

Cargo Tie-down and Release

The HEGS-20 has fifty 2,500-pound-capacity tie-down rings systematically located and mounted on the perforated deck plate of the floor assembly. Figure B-9 demonstrates the use of these tie-down rings for securing a typical cargo-loaded pallet.

Stacking

The structural capability of the HEGS-20 module for withstanding the loads acting on it during the two-module-high stacking condition was demonstrated during the lateral racking test described in a following section. The critical component of the gondola module during the stacking test, the corner column, is subjected to a maximum limit compression load of 9.0 kips when the load distribution is 60/40. During the lateral racking test, the same column is subjected to a maximum limit compression load of 16.0 kips, a substantial increase over that experienced during the stacking test.

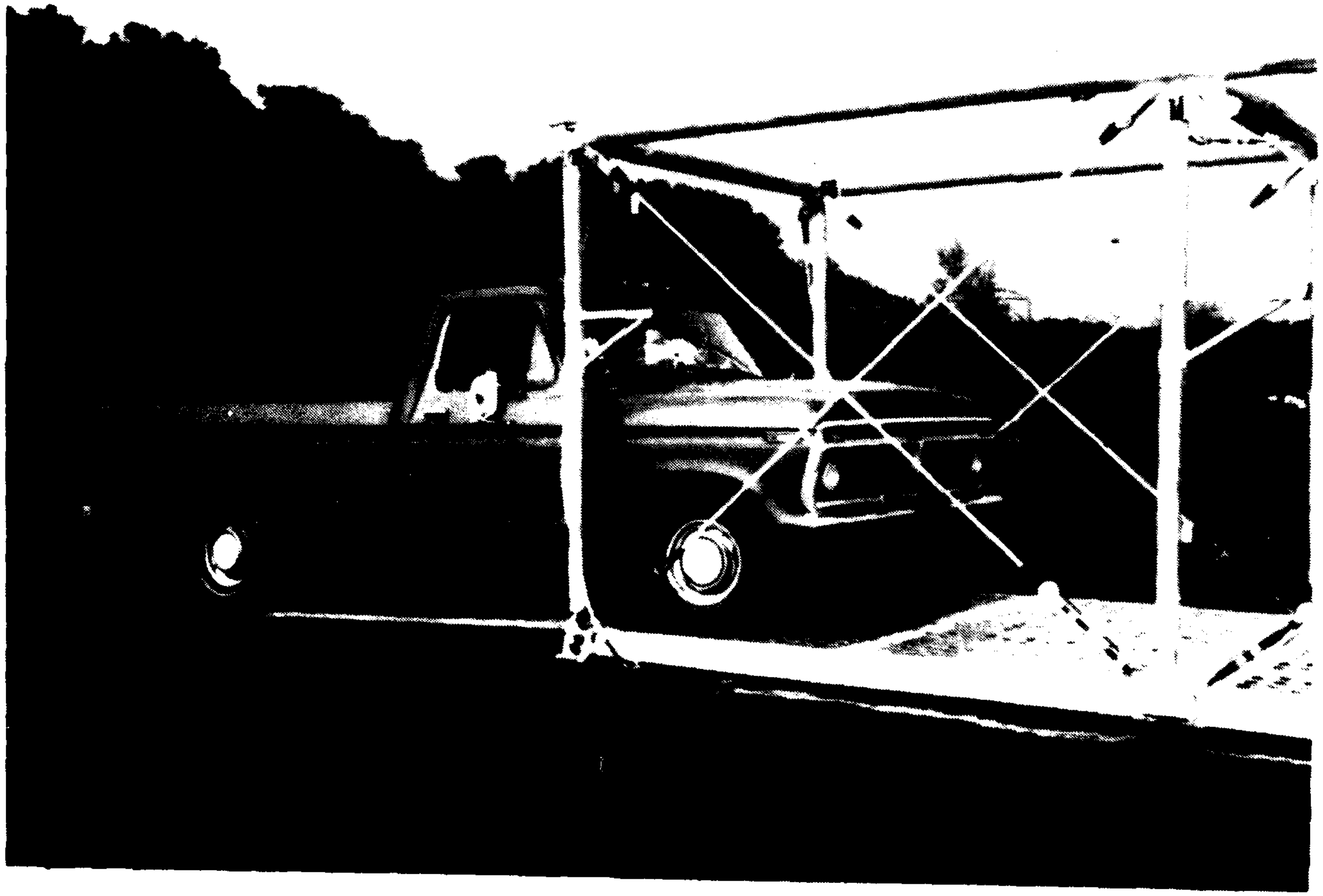


Figure B-4. Drive-on demonstration - side view.

Figure B-5. Drive-on demonstration - end view.

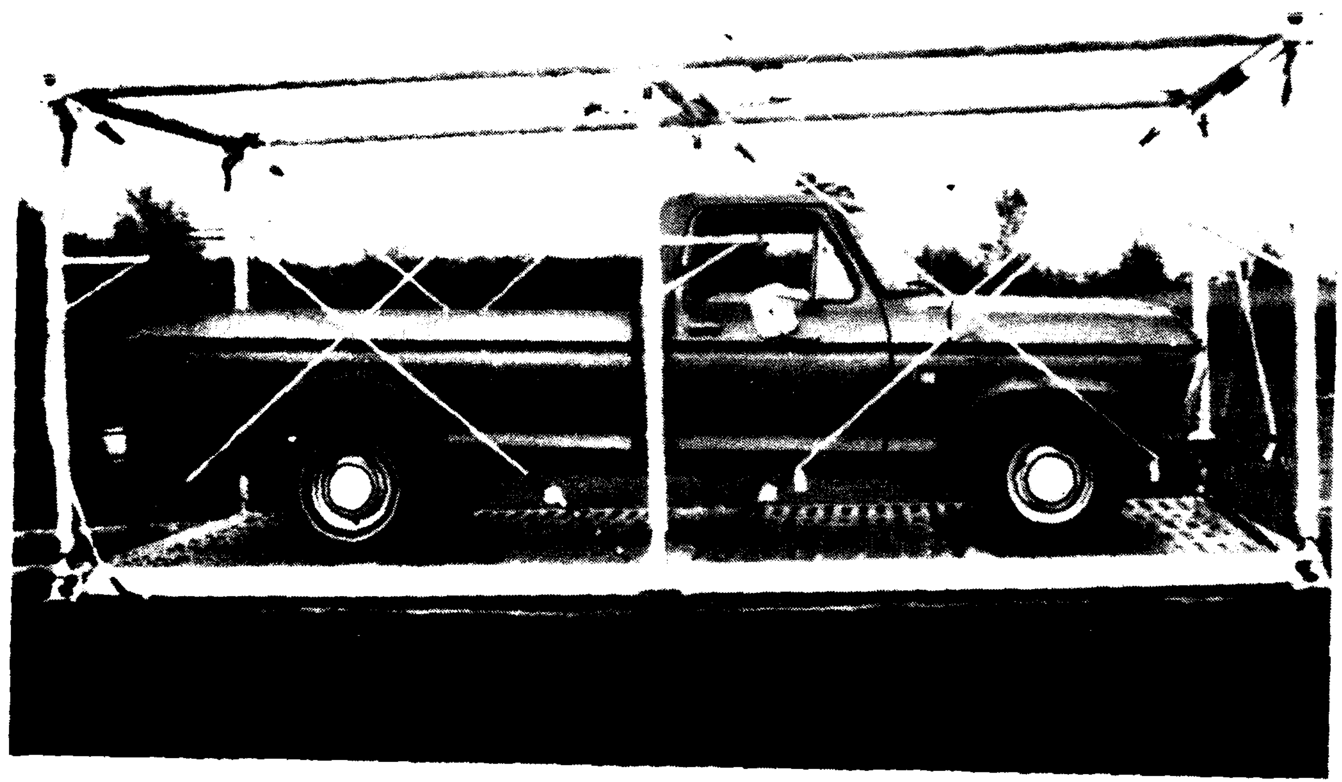
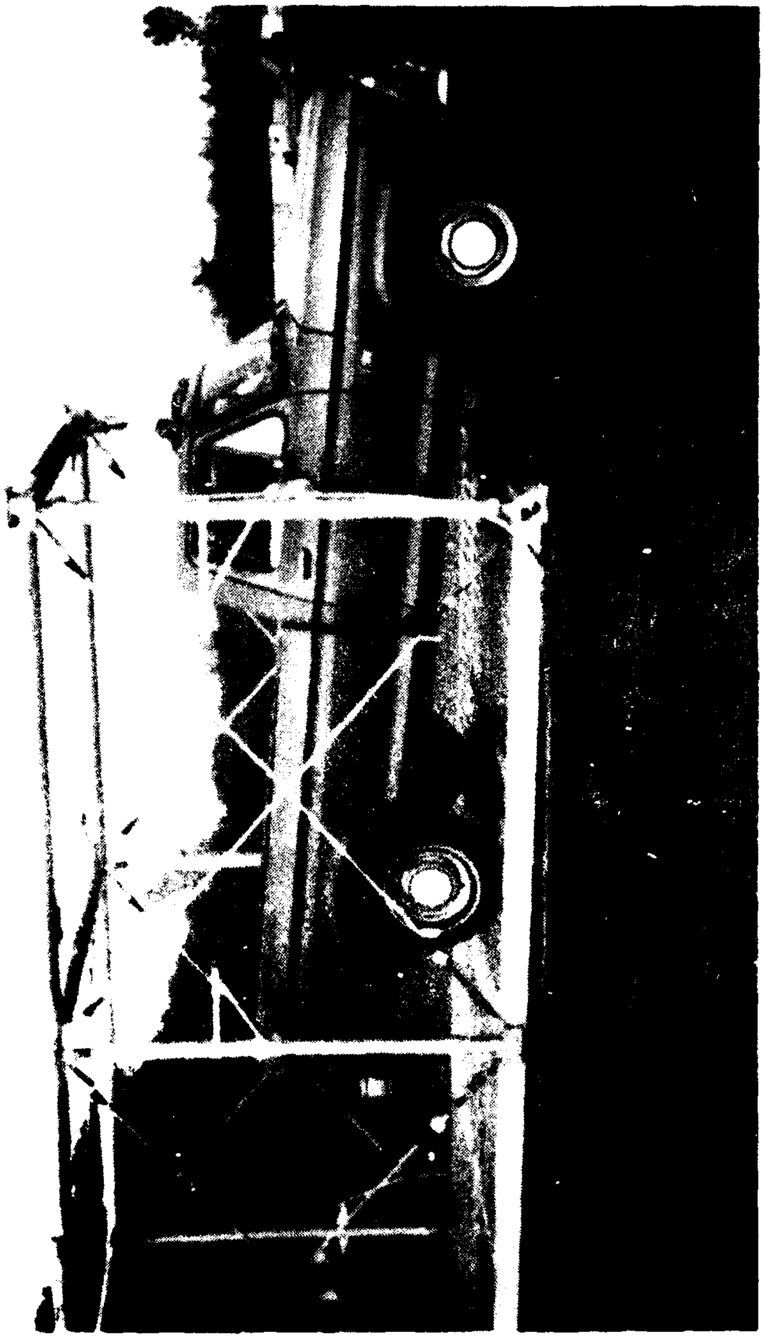
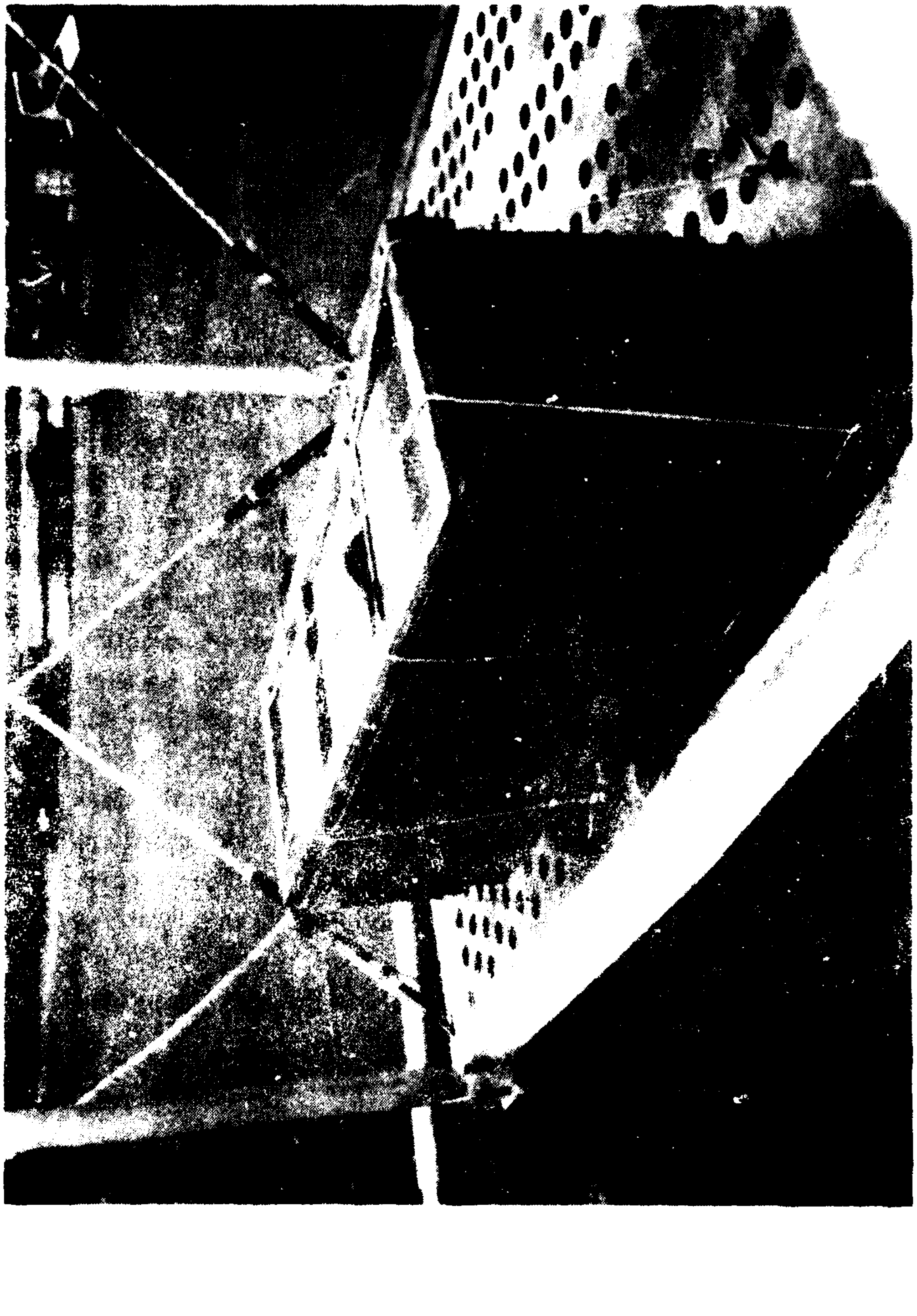


Figure B-6. HEGS-20 module loaded with a truck - side view.

Figure B-7. HEGS-20 module loaded with a truck - end view.





1 g Floor Racking

The 1 g floor racking test was designed to test the ability of the HEGS-20 floor assembly to resist the loads imposed on it during loading or unloading operations on uneven terrain with the center columns and the side diagonals removed. Requirements for this test were to distribute a 1 g load (25,000 pounds) over a footprint area of 83.33 square feet to obtain a uniform loading of 300 psf centered about the 60/40 load distribution center of gravity location while supporting one corner of the floor at a level 6 inches above the remaining three corners.

A precast reinforced concrete block having a footprint area of 83.33 square feet and weighing approximately 25,000 pounds (Figure B-10) was fabricated for this test. Foam blocks placed on 1/4-inch-thick plywood sheets were located on the floor prior to loading the concrete block. The purpose of these foam blocks was to distribute the weight of the relatively rigid concrete block over the flexible floor assembly. Figure B-11 shows the 1 g concrete block being placed on the foam base at the 60/40 load distribution location. After the concrete block was in place, the upper structure was attached to the corner columns, as shown in Figure B-12, and the end diagonals were installed. The corner of the module furthest from the load center of gravity was lifted just enough to permit slipping a 6-inch-thick beam underneath it, as shown in Figures B-13 and B-14. This position was maintained for 5 minutes and then the beam was removed. As shown in Figure B-15, the corner did not return to its original position, signifying that a slight amount of permanent set was experienced. This distortion was not in evidence, however, after the floor assembly was loaded with a 2.3 g limit load for the single-point suspension lift test subsequently performed.

2.3 g Limit Load Single-Point Suspension Lift Test

The 2.3 g single-point lift condition for the HEGS-20 module produces the critical loads in the side diagonals, upper side structure, and floor

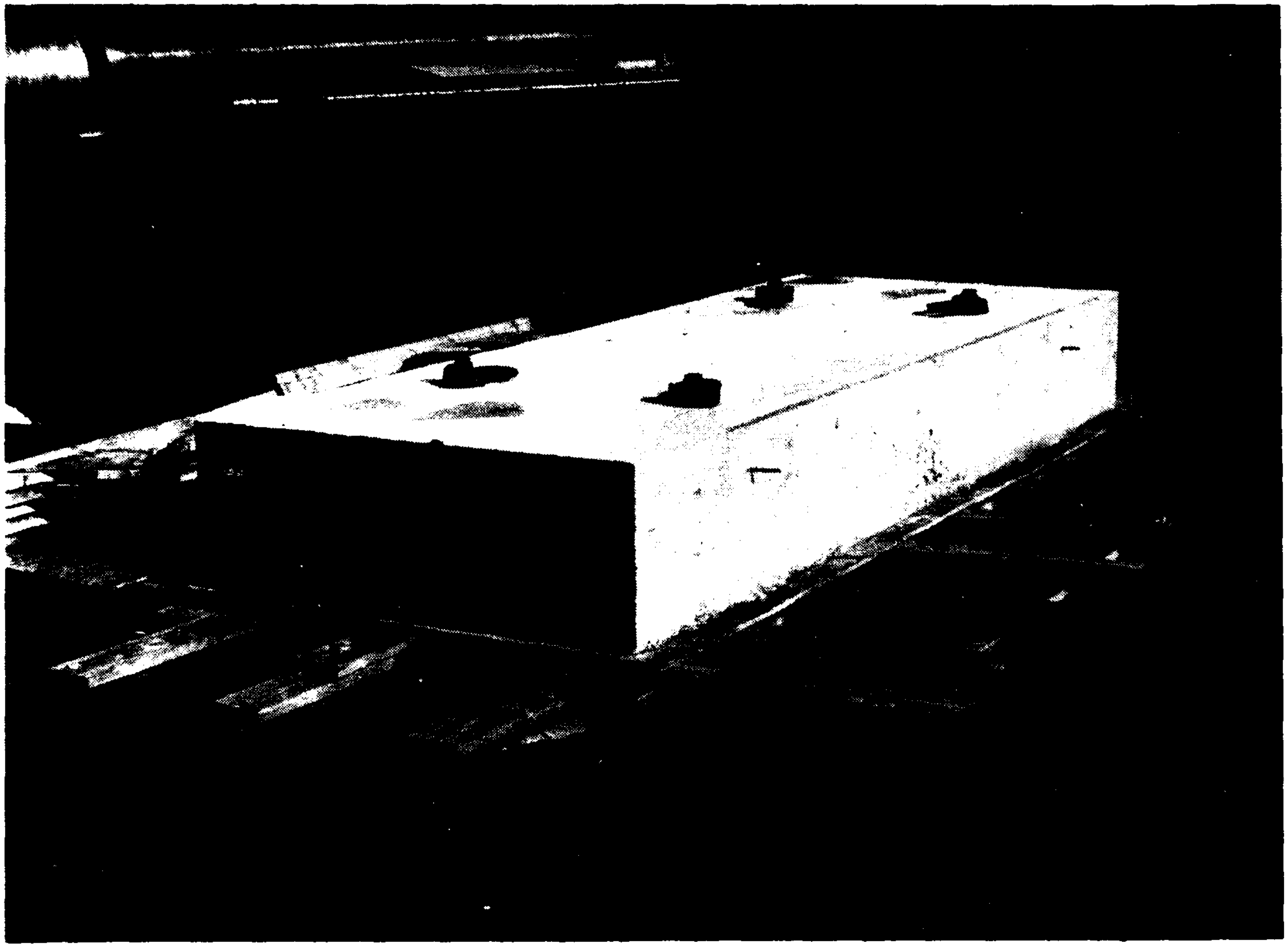


Figure B-10. I a concrete block.

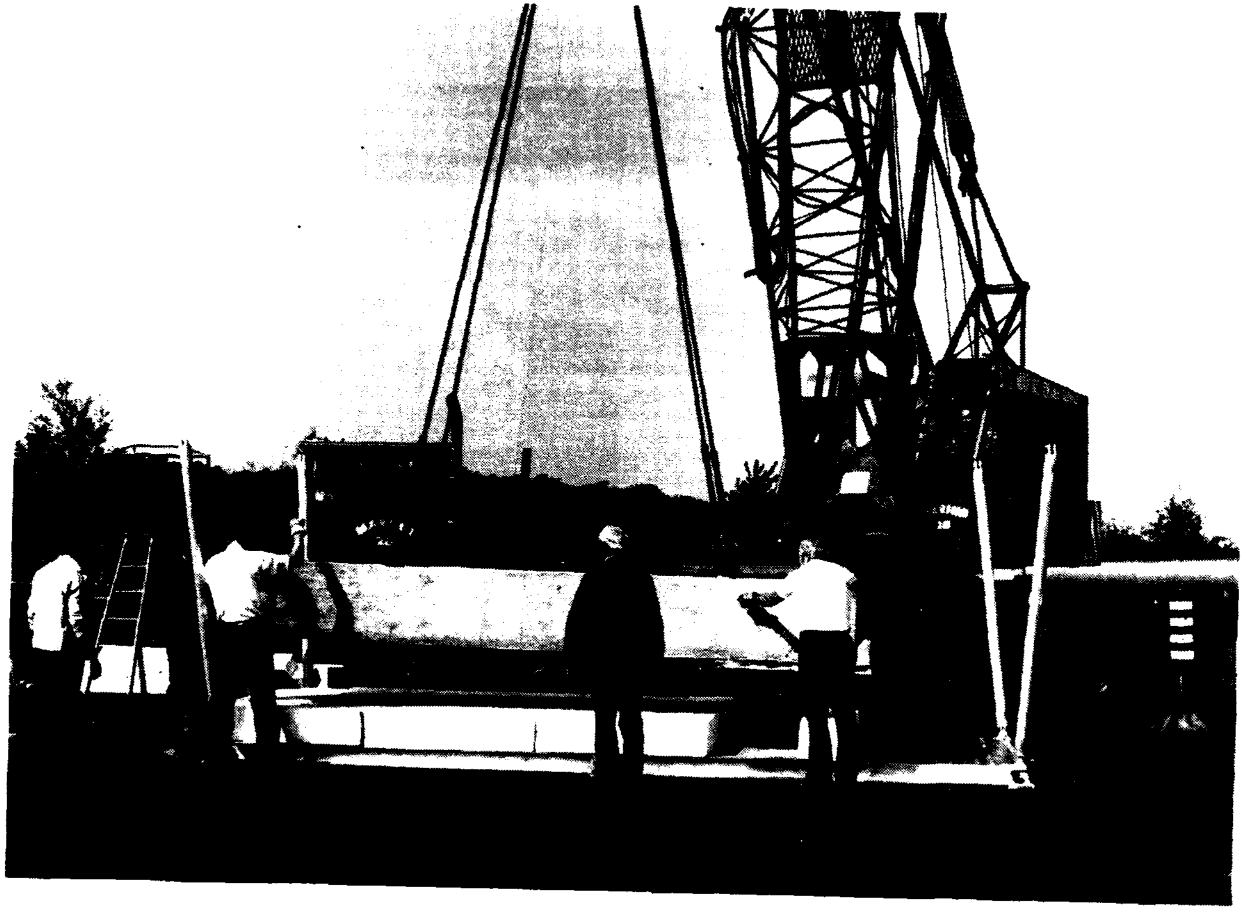


Figure B-11. Installation of 1 g concrete block on foam base for floor racking test.

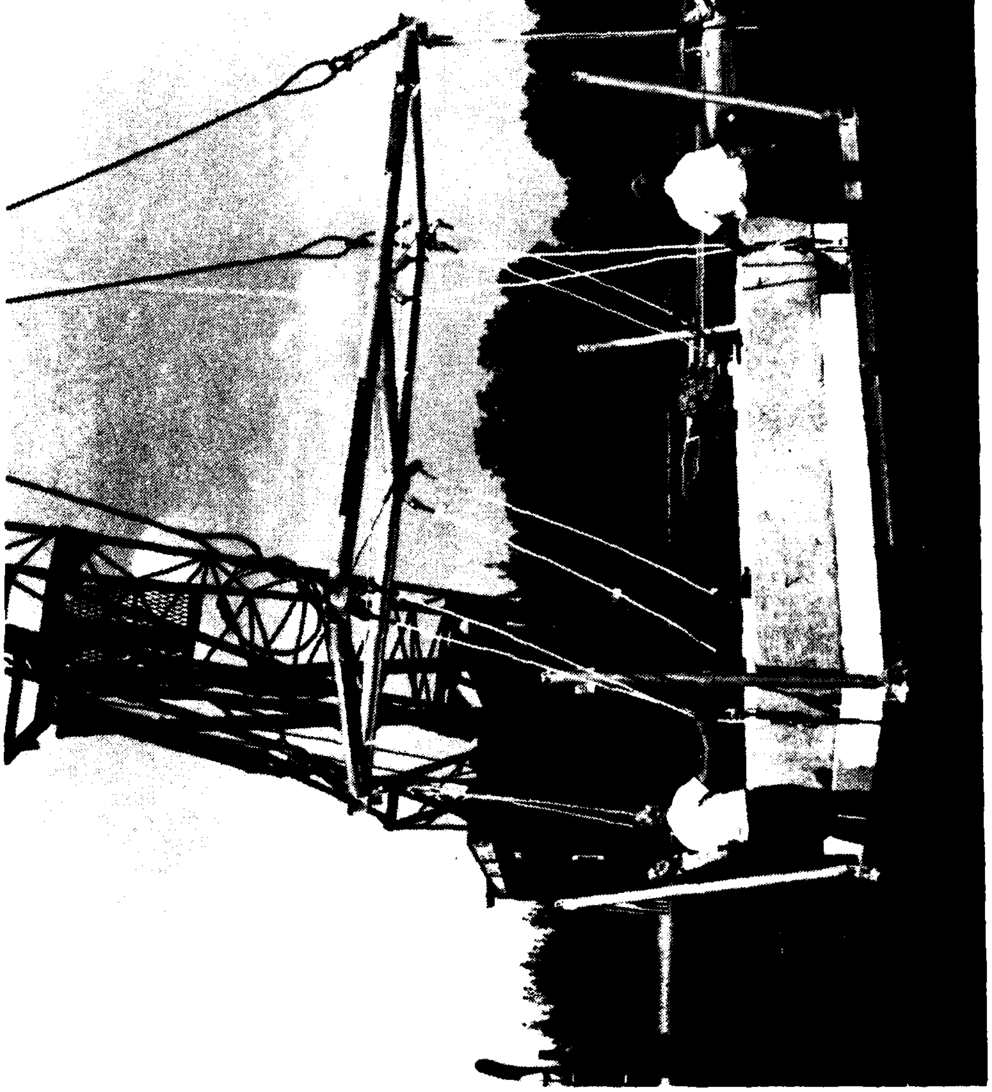
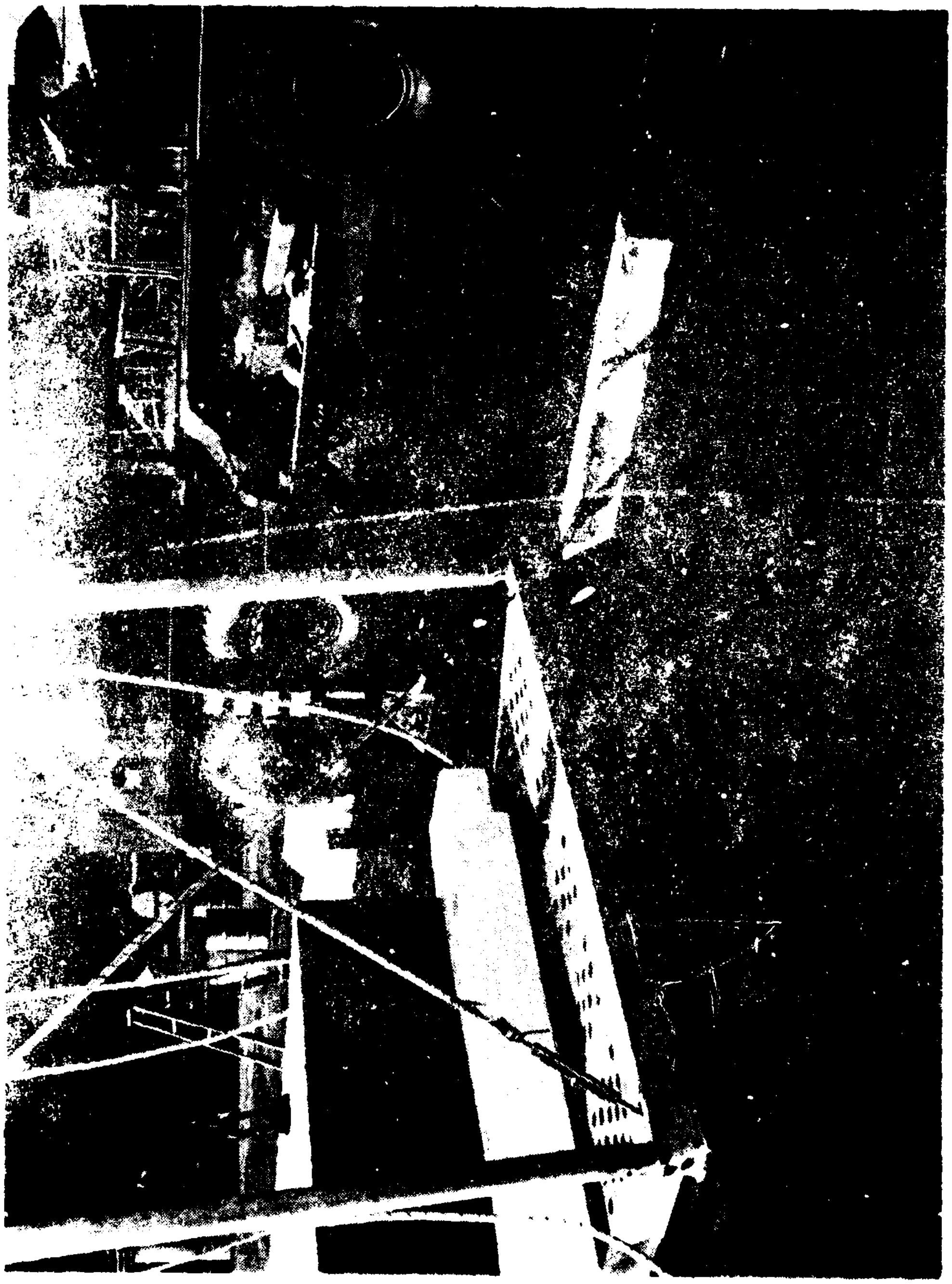


Figure B-12. Installation of upper structure.



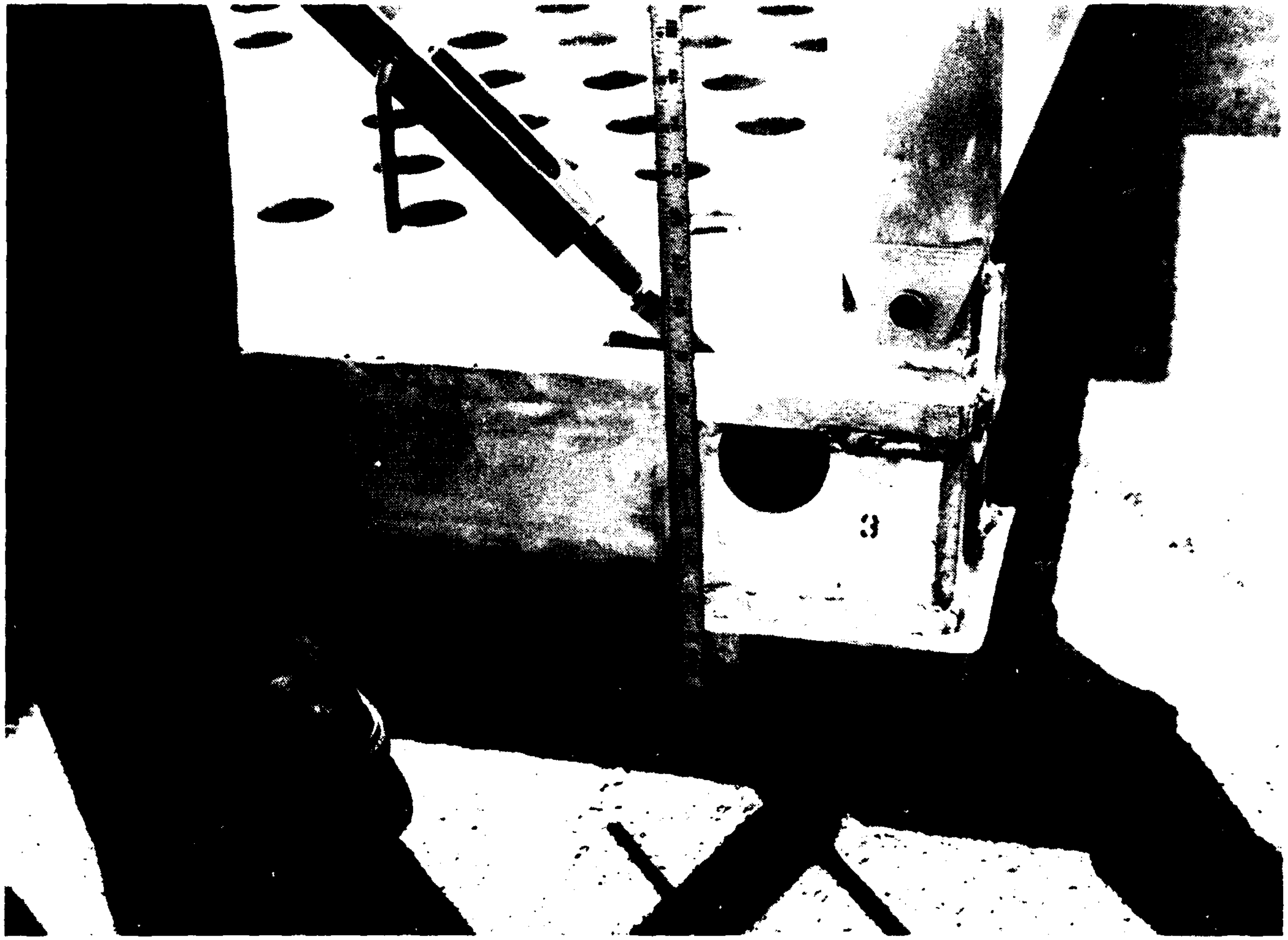


Figure B-15. Distortion of floor assembly after floor racking test.

structure. Requirements for this test were to apply a 2.3 g load (57,500 pounds) at the 60/40 center of gravity location and distribute this load over the footprint area of 83.33 square feet to produce a pressure of 690 psf. The module was then to be suspended by a four-leg sling, the lower end of each leg being attached to an upper corner fitting and the upper end of each leg meeting at a common point.

Lengths of each sling leg were to be equal and were to be orientated such that their true angle from the vertical was approximately 30 degrees.

Two precast reinforced concrete blocks, weighing approximately 1.0 g and 1.3 g, were used to apply the 2.3 g test load to the floor of the HEGS-20 module. As with the 1.0 g floor racking test, contoured foam blocks were placed on 1/4-inch-thick plywood sheets to aid in evenly distributing the load over the footprint area. Figure B-16 shows the two concrete blocks placed on foam blocks at the 60/40 center of gravity position prior to installing the upper structure and diagonals. Figure B-17 shows the upper end of the corner column being pinned to the upper corner fitting lug and also shows the chain assembly used at each upper corner fitting to attach the individual legs of the lifting sling. Additional lead ballast weights were added to the top of the concrete blocks to bring the total weight lifted to the desired 57,500 pounds.

After the module was completely assembled and all of the diagonals tightened, the module was lifted off the ground by a crane. Figures B-18, B-19, and B-20 show several views of the module being suspended clear of the ground.

Upon the completion of this test, the module was visually and dimensionally inspected. During the visual inspection of the underside of the floor structure, five of the welds joining flanges of the intermediate transverse beams to flanges of the continuous longitudinal stringers were found to be cracked, two at one end and three at the other end of the structure. These welds were repaired prior to performing the 0.6 g lateral racking test. A

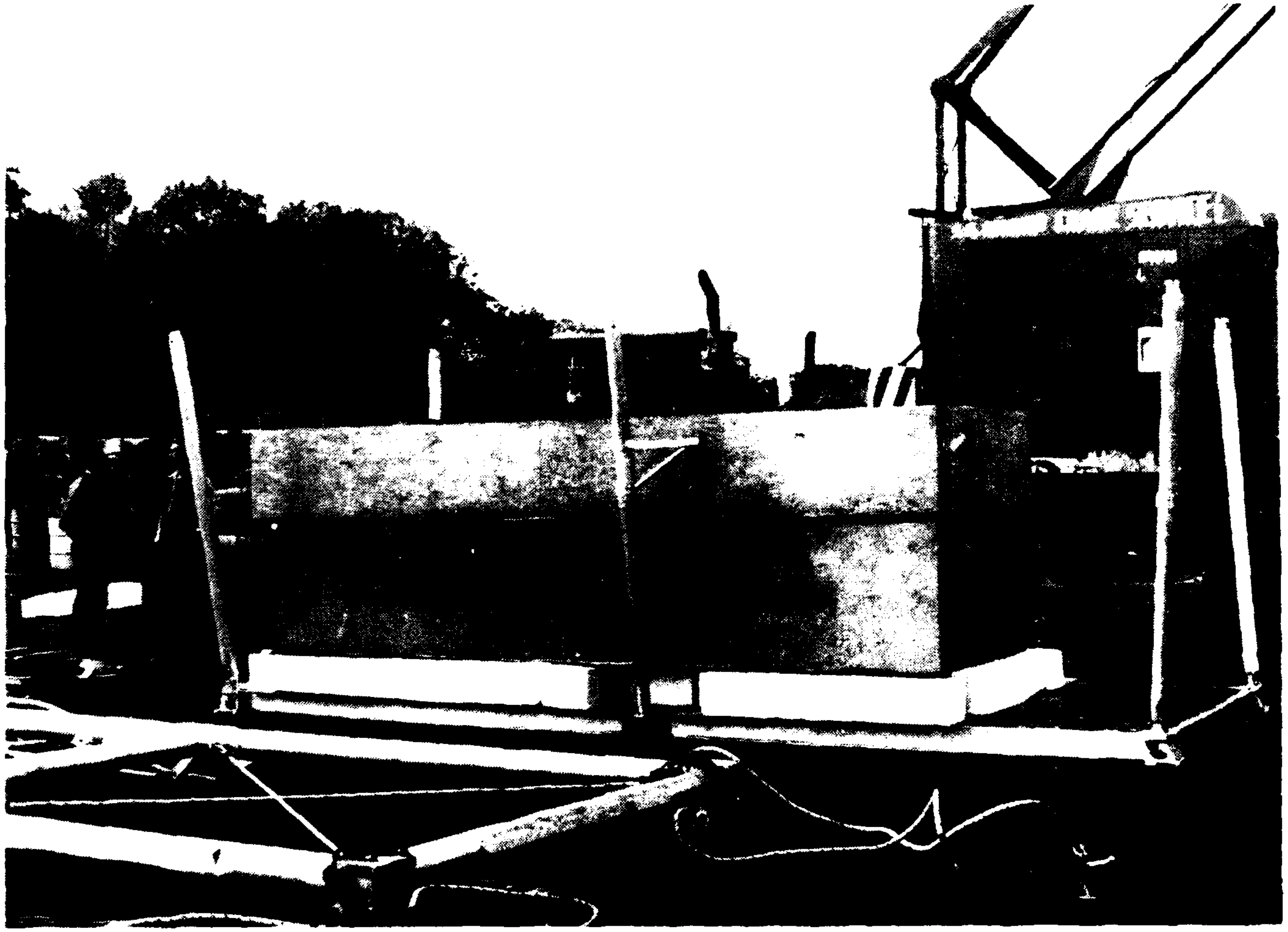


Figure B-16. 2.3 m concrete block, in place for [illegible]

Figure B-17. Sling attachment at upper corner fitting for single-point suspension test.

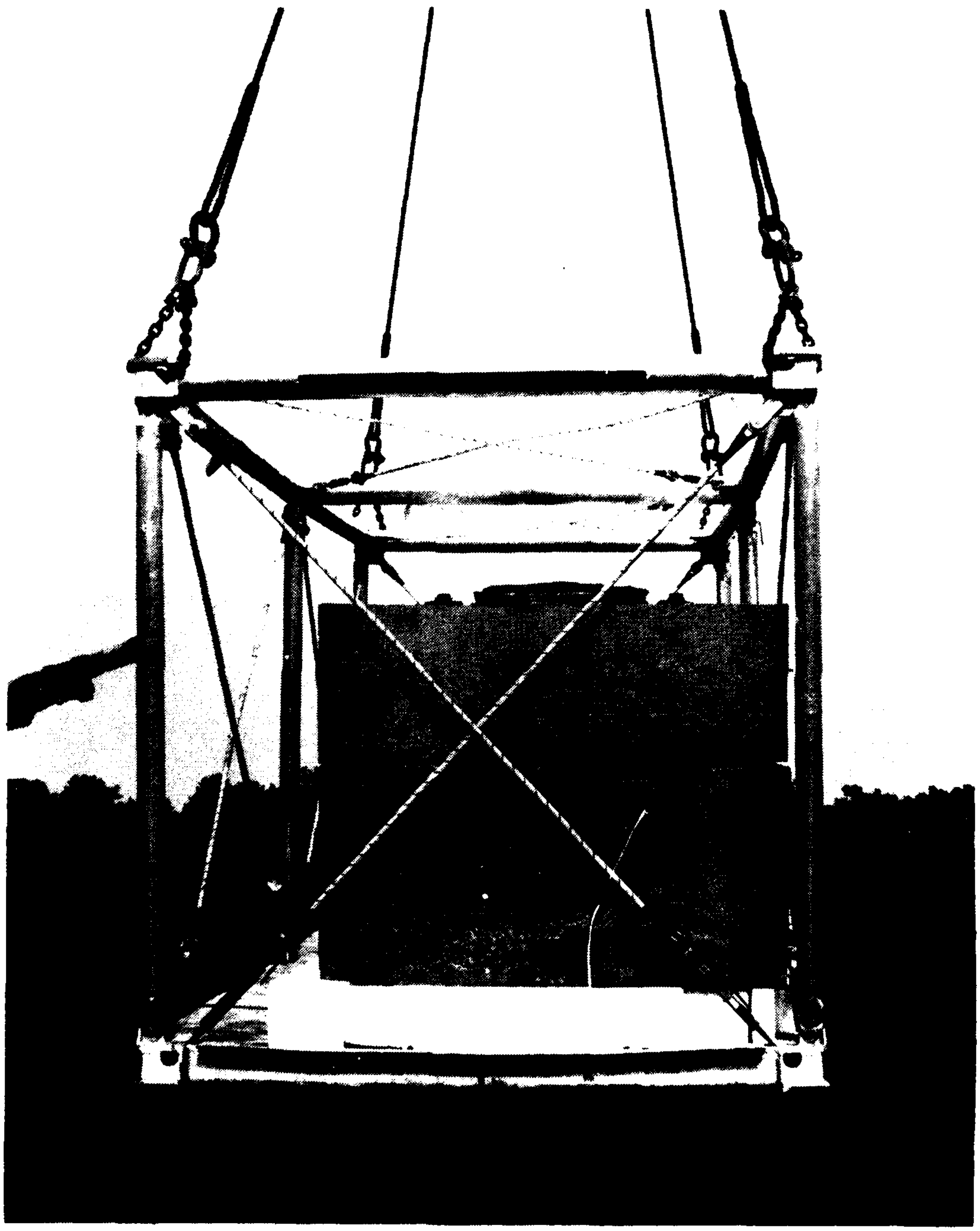


Figure B-18. 2.3 g single-point suspension - end view.

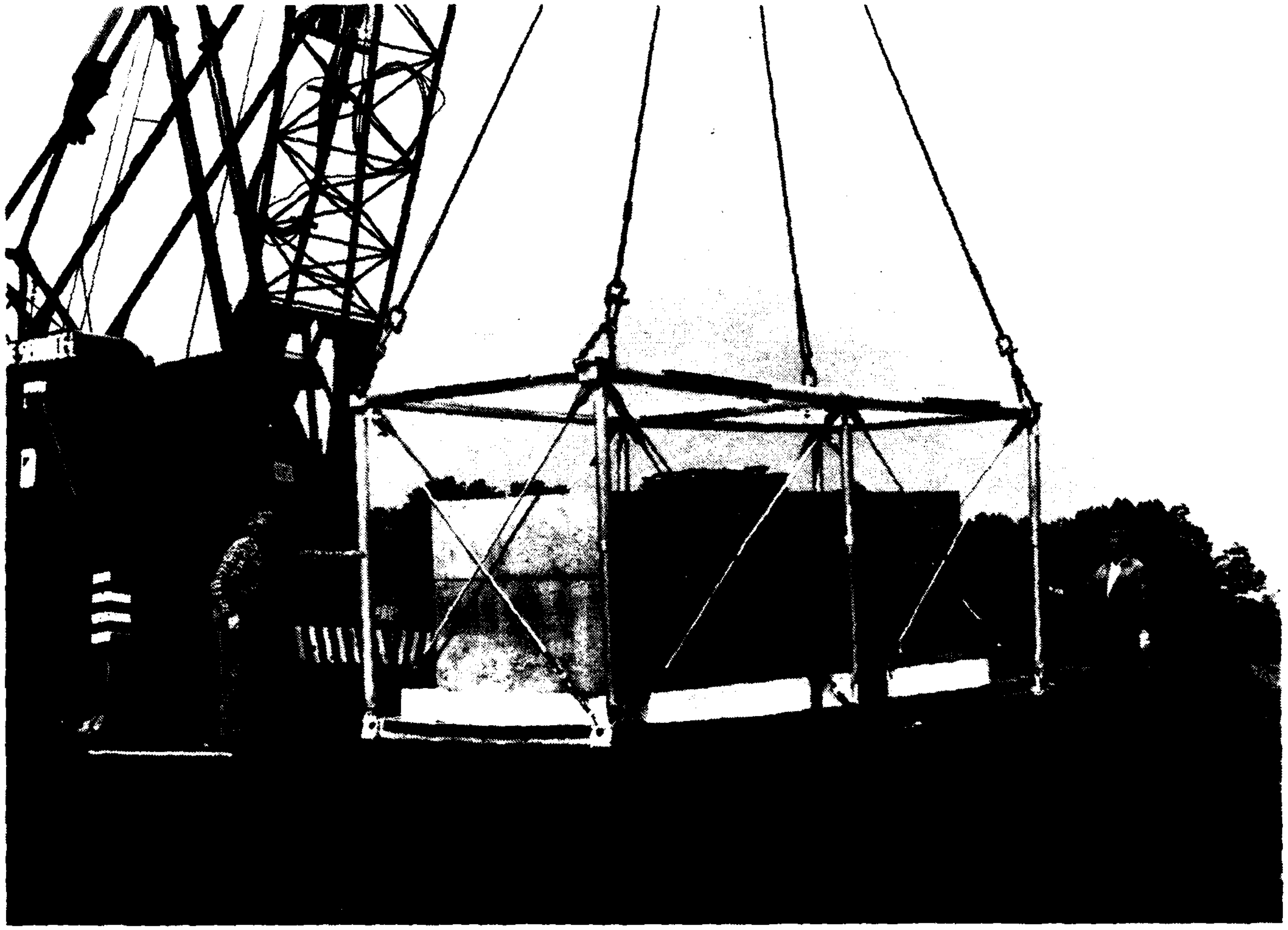


Figure B-19. 2.3 g single-point suspension - corner view.

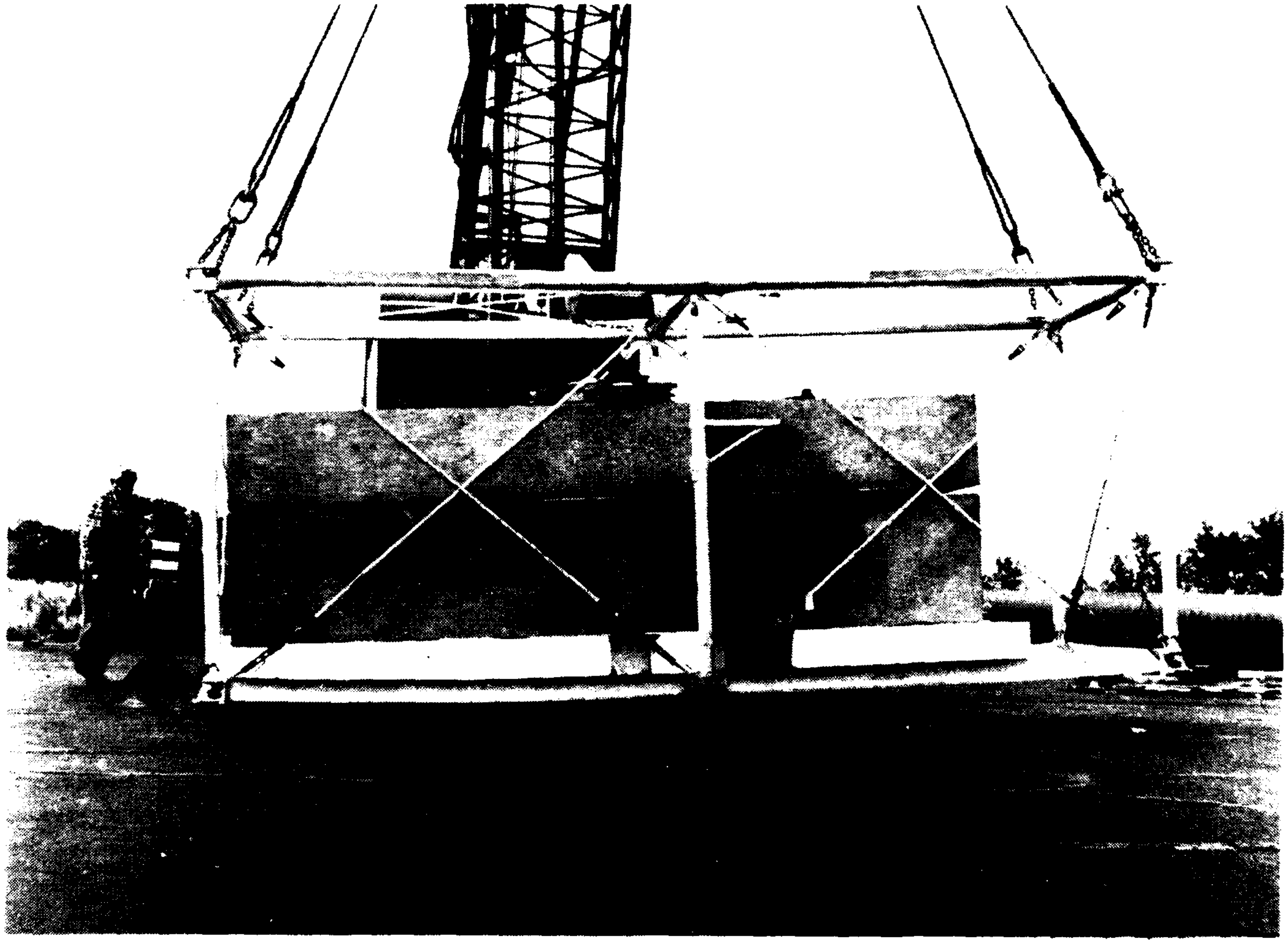
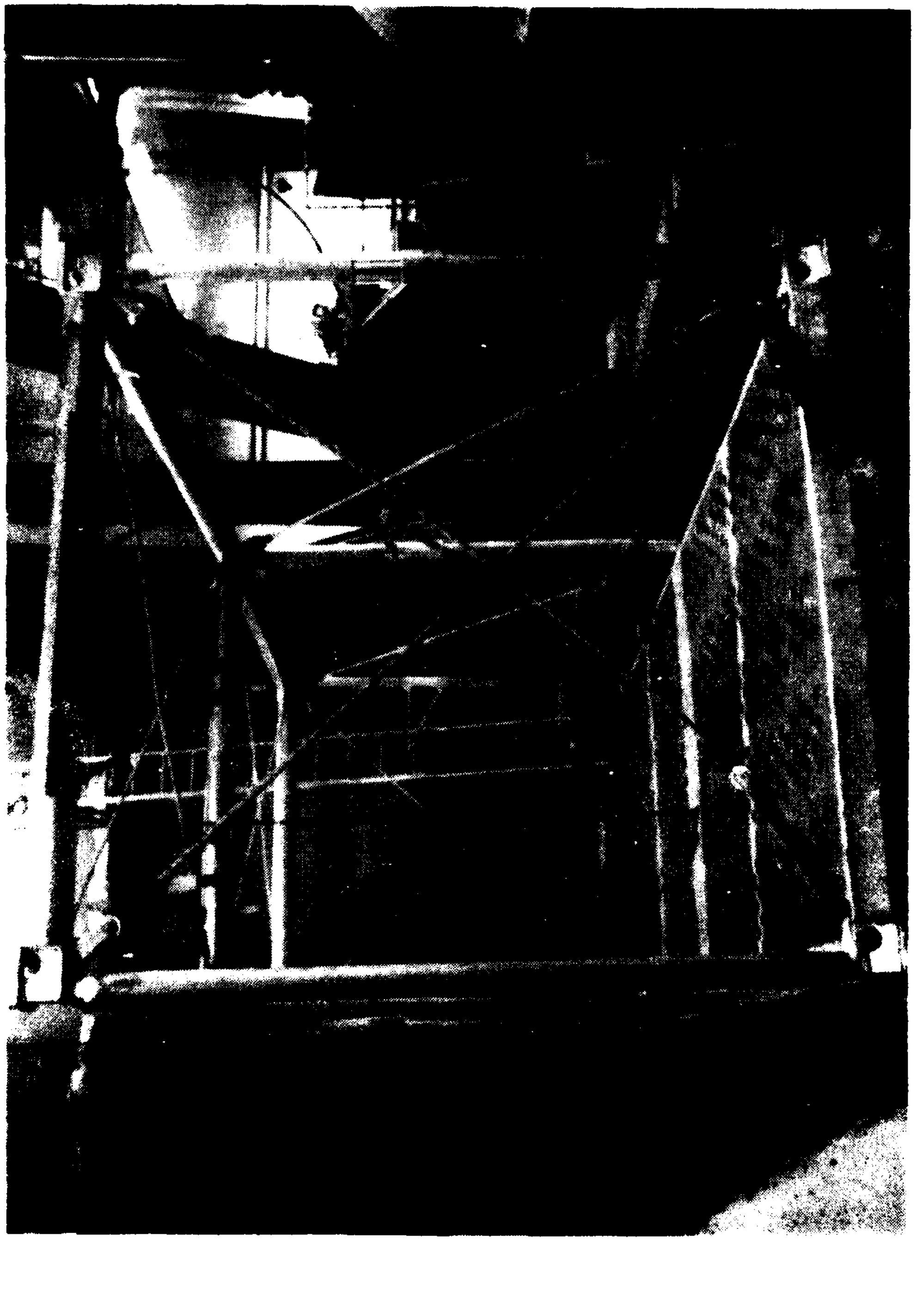


Figure B-20. 2.3 g single-point suspension - side view.

comparison of dimensions taken prior to and after the completion of the 2.3 g limit load single-point suspension test indicated that no appreciable change took place, since dimensional differences that did occur were within the accuracy of the method of measurement.

Lateral Racking

The 0.6 g lateral racking test substantiates the structural capabilities of the corner columns, the end members of the upper structure, and the side and end diagonal assemblies. As shown in Figure B-21, the HEGS-20 module was mounted in a test frame with the module floor restrained from motion. A hydraulic cylinder mounted horizontally to a vertical test frame member and orientated in the end plane of the module was used to apply a compression load to the side of the upper corner fitting. The load, monitored by a calibrated pressure gage, was gradually applied until 0.6 g (15,000 pounds) was reached. At this time, the deflection of the upper structure at the load cylinder was measured as 2.125 inches. Upon release of the load, the upper end of the module returned to within .063 inch of its original no-load position. Inspections performed during and after the test did not reveal any adverse effects or distortions.



LIST OF SYMBOLS

A	Area
b	Bending
B	Slenderness ratio factor
c	Fixity coefficient; distance from neutral axis to extreme fiber
CG	Center of gravity
D	Diameter
E	Modulus of elasticity
f	Calculated stress
F	Strength
g	Force of gravity
I	Moment of inertia
L	Length
M	Moment
p	Unit pressure
P	Load
R	Radius
r	Radius of gyration
S	Section modulus
t	Thickness
W	Width or weight
x, y, z	Coordinates
[illegible]	Density

Subscripts and Superscripts

b	Bending	s	Shear
br	Bearing	t	Tension
c	Compression; mid-diameter	u	Ultimate
H	Horizontal	v	Vertical
o	Yield	y	Yield

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